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PRODUCTION TO FLOOD PROOFING

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**CENTER FOR URBAN STUDIES
THE UNIVERSITY OF CHICAGO**

**Introduction to Flood Proofing
An Outline of Principles and Methods**

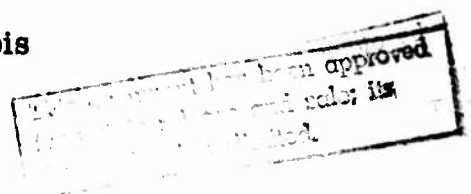
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**Chicago, Illinois
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Preface

Flood proofing is a body of techniques for preventing flood damage to the structure and contents of buildings in a flood hazard area. This publication on structural flood proofing is intended to acquaint public officials, building owners and professionals with the essential principles and to outline and illustrate a number of simple but effective measures for reducing flood damage. The report should be of particular service to officials of Federal agencies having responsibility, under Executive Order 11296, for preventing flood damages to Federal structures. It is also hoped that it will serve as an outline for engineers, architects and other professionals of problems associated with either preventing entry of water into buildings or minimizing the damages from flood waters.

Introduction to Flood Proofing was prepared as part of a study of certain aspects of flood plain management financed in equal parts by the U. S. Army Corps of Engineers and the Tennessee Valley Authority. It presents information and guidance immediately available. Further study of flood proofing and its application is necessary before a more detailed manual can be issued.

The preparation of this report was carried out under the administrative direction of Jack Meltzer, Director, Center for Urban Studies, University of Chicago. His overall guidance is warmly acknowledged and his critical and perceptive review of the draft manuscripts was particularly useful in the preparation of this report.

Walter G. Sutton, Office of Chief of Engineers, U. S. Army Corps of Engineers, acted as the Contracting Officer and provided guidance, encouragement and assistance throughout the study. John W. Weathers, Chief, Local Flood Relations Staff, Tennessee Valley Authority, was the principal contact with TVA, and was a key expeditor of the study.

James E. Goddard, a consultant on flood plain management in the Office of the Chief of Engineers, U. S. Army Corps of Engineers, reviewed the report and made beneficial comments. Charles A. MacNish, Chief, Engineering Division and James S. King, Chief, Planning Division, North Central Division, U. S. Army Corps of Engineers, also reviewed the manuscript and advised on all aspects of the report. Others in the North Central Division who assisted in the study were John Harbourne and John Stephenson.

Special thanks are due to the following who generously agreed to review early drafts of the booklet: Brian J. L. Berry, Wesley C. Calef, and Gilbert F. White, of the University of Chicago, and John Radar of Urban Planning Consultants, Chicago.

Information concerning existing flood proofed buildings was made available by several organizations and individuals. For their assistance in providing photographs, drawings, and other information, we particularly wish to thank I. M. Laucik, Building Superintendent, Joseph Horne Company, Pittsburgh, Pa.; William Mueller, Vice President, Equitable Life Assurance Society, Pittsburgh, Pa.; William Sanford, Sanford Building, Reno, Nevada; E. Lee Stanley, LaGrange, Illinois; Leo Koeberlein, Managing Editor, and George Ploesch, Building Superintendent, Pittsburgh Press, Pittsburgh, Pa.; and John Webster Brown, Registered Engineers, Reno, Nevada.

The graphics in this booklet were prepared under the direction of Gerald Pyle, Cartographer for the Center for Urban Studies, with the assistance of R. Fred Meeker. Doris Bennisson served as Project Coordinator. L. S. Botts assisted with the final editing.

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Chapter I. The Uses and Limitations of Flood Proofing

Flood proofing consists of those adjustments to structures and building contents which are designed or adapted primarily to reduce flood damages. Such adjustments can be scheduled to be undertaken in existing buildings during periods of remodeling or expansion. Also, they can be incorporated into new buildings during initial construction at locations where studies have shown that such buildings would constitute a proper use of a flood plain.

Flood proofing, like other methods of preventing flood damages, has limitations. It can generate a false sense of securing and discourage the development of needed flood control or other actions. Indiscriminately used, it can tend to increase the uneconomical use of flood plains. Applied to structurally inadequate buildings, it can result in more damage than would occur if the building were not flood proofed.

The flood proofing technique also presents certain practical difficulties. A complex pattern of land and building ownership would present problems in cooperation before a community wide program of flood proofing could be carried out. In addition, retail businesses as well as houses frequently change ownership and this tendency would discourage investments for producing primarily long term flood protection benefits. Another complication is the requirement of accurate and timely flood forecasts for successful flood proofing operations in some areas.

The Values of Flood Proofing

Flood proofing has important values when treated as part of a broader program for comprehensive flood plain management. Continued occupancy of developed flood plain sites, and even new development of such sites, may become necessary in some low lying areas--especially in certain urban areas where a shortage of land may offer no alternative.

In addition to its principal values of permitting occupancy in flood plains and enabling a building to function during flood periods, flood proofing has some other benefits:

1. It offers an additional tool in a comprehensive flood damage reduction program.
2. It can increase the protection afforded by partial protection flood control projects.
3. It may improve the availability of flood insurance.
4. Properly understood, it can increase interest in flood damage reduction programs by heightening the awareness of flood risk.

Flood proofing is not a cure for all flood problems. Rather, it should be considered as one device among an array of available flood damage reduction measures, including land use regulation and change, flood control projects, flood fighting, flood relief, and flood insurance. A comprehensive flood plain management program would probably involve the use of several or all of these techniques.

When is Flood Proofing Appropriate?

The characteristics of flooding vary from flood plain to flood plain and the type of development on flood plains is highly diverse. This variation makes it difficult to select the flood damage reduction instruments best suited to a given flood plain situation unless a detailed analysis is undertaken. The appropriateness of flood proofing in any given region depends upon the stage of flooding, the velocity of flow, the duration of the flood period, the uses being made of the flood plain, and the relationship of flood proofing to other flood damage reduction measures.

A flood proofing program would normally warrant serious consideration as a means of flood damage reduction in the following circumstances:

Where studies have concluded that it is not economically feasible to provide flood control structures, flood proofing could provide a substitute means of reducing flood losses.

Where authorized flood control projects have not been constructed because of lack of local cooperation, flood proofing could provide property owners with an opportunity to reduce their flood risk.

Where utilities, manufacturing plants, and navigation terminals require riverfront locations to function effectively, flood proofing could provide the owners of these facilities an opportunity to achieve a degree of flood damage reduction. The highest practicable level of protection should be afforded to assure continuation of utilities.

Where flood proofing and flood insurance are closely allied, a property owner could elect to flood proof to reduce his flood risk in order to obtain more favorable flood insurance rates.

Where flood control projects have provided only partial flood protection, flood proofing could enable property owners to achieve a higher degree of protection than would otherwise be provided.

In actual cases where buildings have been flood proofed in accordance with plans developed with professional engineering and architectural assistance, flood proofing has performed satisfactorily and has mitigated flood losses. A number of examples will be cited in later chapters.

Flood Proofing and Flood Control

Flood control measures, such as reservoirs, levees, channel improvements, and watershed treatment, seek to keep flood water within established channel banks or floodway limits. Flood proofing seeks to reduce damage once the water reaches a building. Although in most instances the benefits of flood control will exceed the costs, there are many communities where flood control measures are not economically justified. In such communities, the flood proofing of individual structures could result in a substantial reduction in flood losses.

In other communities, where flood control projects are economically justified, as many as 20 years have elapsed between authorization and actual construction of an approved project. In such situations, flood proofing could be undertaken as an interim flood damage reduction measure for selected buildings, and either discontinued with the construction of the flood control project or used in some cases to attain an additional degree of protection than that provided by the flood control project.

Flood Proofing and Flood Plain Regulations

To help bring about the economic use of flood plains, states, counties and municipalities frequently adopt comprehensive flood plain regulations. These regulations may be incorporated in building codes, subdivision regulations, or zoning ordinances. Since the emphasis is on promoting proper use, rather than on prohibiting use, flood proofing can be a useful element in flood plain regulations.

When studies show parts of a flood plain to be potentially suited for more intensive

use, flood proofing would allow development in these hazardous areas. Because of the adjustments made, however, the potential flood damages are reduced and the pressures for a public flood control project are likewise reduced. From this vantage point, flood proofing techniques are important, not only to individual property owners, but to public officials interested in proper flood plain management.

A flood control approach now being considered is to clear the flood plain through a system of tax rebates which reduce a property value to zero over a 10 or 20 year period. In such an approach, flood proofing could furnish protection to a building during the amortization period prior to its demolition.

Flood Proofing and Flood Insurance

Flood proofing and flood insurance are interrelated and can be considered together in a comprehensive program for flood damage reduction. Effective flood proofing could be used to reduce flood risks to a level where it would be possible for private insurance firms to underwrite flood insurance at a marketable rate. This is the situation in the Golden Triangle of Pittsburgh, where flood insurance on a private commercial basis is available to the J. P. Horne Company because of their flood proofing program.

Flood proofing is used to protect against the losses that would otherwise occur from the more frequent flood events, while flood insurance is used to protect against losses from the less frequent event--the large magnitude flood which occurs so infrequently and has such a high stage that it is not economically feasible to flood proof against it.

If flood insurance becomes more widely available, the effect should be to stimulate flood proofing, since the insuring companies would encourage protection of the insured properties and would reward such protection with reduced flood insurance rates. In a federally sponsored flood insurance program, for example, the premium schedule would probably reflect degrees of flood risk. A flood proofed building able to withstand a flood stage that was considered a low risk would most certainly obtain a more desirable premium rate. The potential dollar savings in premiums could serve to encourage property owners to use flood proofing measures.

Flood Proofing Decisions

The protection of property from flood losses depends, in part, upon the owner's awareness of the flood hazard and a willingness to do something about it. To arrive at

feasible decisions pertaining to flood proofing, the property owner must recognize potential flood problems and their related effects. This knowledge can be obtained in several ways.

The worst way, of course, is personal experience--to have seen one's own building damaged and its contents ruined (Figure 1) and to have suffered the labor and cost of cleaning up (Figure 2). There are other ways, however.

A building owner may become aware of a flood hazard from a "near miss" when a flood almost caused a catastrophe. If flooding occurred before the present owner located on the site, he may have been informed by others that the property he now occupies had been severely damaged in the past.

The owner may have been unaware of his flood exposure, until he heard of reports which outlined

Figure 1.-Learning of the flood hazard through experience.





Figure 2.-The Aftermath of Flooding: Water Damage and Clean-up.



Figure 3.-Using Flood Plain Map to Determine the Degree of Flood Risk.

exposure, until he heard of reports which outlined flood problems,¹ or saw maps showing areas subject to flooding (Figure 3). The flooding problem may have been called to the owner's attention by public officials when they embarked upon a program of flood plain management by adopting building, subdivision, and zoning ordinances which included controls over developments in flood plains.

Information on the flood hazard may come from any of these sources, but the determination of the stage of protection (Figure 4) and the formulation of a course of action to reduce losses is complex and would require professional assistance.



Figure 4.-Decision to protect against the maximum flood of record.

If a property owner decides to explore the possibilities of flood proofing, he should seek the help of professionals who have a working knowledge of structures and who have had experience in flood proofing. An examination of the building should be made by qualified professional engineering and architectural personnel. The structural soundness of the building must then be related to the depth and duration of flooding, and to the soil foundation conditions (Figure 5).

¹Such information has been made available for many areas in flood plain information reports of the Corps of Engineers, local flood reports of the Tennessee Valley Authority, and Hydrologic Atlas Maps of the U. S. Geological Survey.



Figure 5.-Engaging professionals to assist in a flood proofing program.

A building owner will naturally want to measure an expenditure of money for flood proofing against the protection he receives. For this purpose he should make it a point to include a benefit-cost analysis as part of his inquiry. This involves determining the dollar extent of the flood hazard by first calculating the probability of floods of various levels at the site and then estimating the damage to the particular building from those levels of flooding. The result is an estimate of dollar loss from flooding which is considered as the flood proofing benefit--that is, the amount saved by flood proofing to various levels of protection. This benefit is then matched against the cost of flood proofing on an average annual basis to produce a benefit-cost ratio. A fuller evaluation of flood proofing is presented in a previous report entitled Flood Proofing: An Element in a Flood Damage Reduction Program.¹

Professional hydrological advice, from such agencies as the U. S. Army Corps of Engineers or the Tennessee Valley Authority, is available in calculating the general flood hazard at a site. Estimating the probable damage from various flood levels is usually done best by the building owner himself, in consultation with a professional engineer or architect. The same professional can then estimate the cost of flood proofing over a prescribed time period.

The decision to flood proof, or not, rests finally with the building or property owner. A decision against altering the building, for whatever reason, need not necessarily mean a total discard of all flood proofing techniques. A plan of action as simple as the water proofing of machinery, the disconnection or raising of electrical circuits, etc., or a plan for the orderly removal of machines or merchandise, may be the only logical recourse in some circumstances; but even these measures will reduce flood losses, sometimes substantially. Another approach would be to permanently reorganize the use of space in the building.

Flood proofing measures that are temporary safeguards require advance preparation, as do more complicated programs, and plans should be developed for their implementation. Any step which is carried out primarily to reduce the probability of damage is an ingredient in a flood proofing program.

¹John R. Sheaffer, Flood Proofing: An Element in a Flood Damage Reduction Program, Department of Geography, Research Paper #65, University of Chicago (Chicago: by the Author, 1960), pp. 27-42.

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Chapter II. The Physical Environment and Types of Flood Proofing

Buildings on flood plains can be damaged by seepage of flood waters through walls and foundations, by ground-water pressure on floor slabs and walls, by the backup of water through sewerage systems, by the entrance of flood waters which overtop channel banks and inundate flood plains, and by ice jams. The physical environment is an important factor in determining which sources of flood waters are present at a particular location, and thus will influence the nature and design of flood proofing measures.

The permeability of the earth materials, the stability of flood plain slopes, and the interconnection of flooding with the ground water resource are significant environmental elements to be considered. Under some conditions, these environmental elements could rule against the use of flood proofing, while in others the condition could promote the use of flood proofing.

Permeability of Site Materials

The permeability of the materials at a building site largely determine the movement of ground water around and under the foundation walls and floor slab. In some environments, ground-water pressure will build up against such buildings. In these situations a drainage system can be considered as a means to relieve the ground-water pressure by creating a cone of depression (pumping cone) under the building.

Permeability, in part, determines the level of the zone of saturation (commonly known as the water table). Beneath this level, problems of underground seepage control are most likely to be encountered. However, such problems can also be encountered above this level in areas which have localized "perched" water table conditions.

The range in permeability of some common types of earth material is presented in the following table. In materials of low permeability, such as clay, the quantity of ground water flow into underground openings is likely to be small even at relatively high gradients and could be drained only with a close network of tiles. In materials of high permeability,

TABLE 1: RANGE IN PERMEABILITY FOR SELECTED MATERIALS

Selected Materials	Range in Permeability
Unweathered clays	Low
Very fine sands, silts; mixtures of sand, silt, and clay; (Common Flood Plain Deposits)	Intermediate
Clean sands, mixtures of clean sands and gravels (Course textured alluvial fan, glacial outwash)	High
Clean gravel	Very High

Source: Based on Todd, Ground Water Hydrology (1959), p. 53.

such as sand and gravel, the quantity of flow, even at relatively low gradients, may be so large that it would be extremely difficult to prevent the level of ground water saturation from rising even with a drainage system.

The pressure exerted by ground water on structures is that of the upward and lateral hydrostatic pressures which are related to ground water levels. Buildings must have the structural strength to withstand these pressures or they must be relieved by a drainage system. The feasibility of relieving pressure by drainage (pumpage) is a function of the permeability. Many of the common flood plain deposits fall within the intermediate range of permeability and are susceptible to pressure release by pumped drainage. However, many flood plains are layered and have widely varying permeability.

At locations where landslides or land slumping are prevalent, it appears that flood proofing would not be appropriate. Rather, effort should be directed to restricting the development of such areas and clearing them of existing potentially dangerous structures.

Flood Forecasting

Reliable, accurate, and timely forecasts of flooding and flood stages are a prerequisite for a flood proofing program. The main stems of the major river valleys are generally provided with efficient flood forecasting services. However, many urban areas are not now provided with such services. It may be possible to provide these services in the future if staff, equipment, and data are expanded. In the light of this shortcoming, the Bureau of the Budget's Task Force on Federal Flood Control Policy has recommended that an improved system of flood forecasting should be developed by the Environmental Science Services Administration as part of a disaster warning service. As flood forecasts become more widely available, the feasibility of using flood proofing as a means of flood damage reduction is also broadened.

Types of Flood Proofing Measures

Flood proofing measures can be classified into three broad types. First, there are permanent measures which become an integral part of the structure and, in consequence, are rarely noticeable. Second, there are contingent or standby measures which are used only during floods, but which are constructed or made ready prior to any flood threat. Third, there are emergency measures which are carried out during a flood according to a predetermined plan.

Permanent Flood Proofing Measures. - These measures essentially involve either the elimination of openings through which water can enter or the reorganization of spaces within buildings. In some instances, they yield multiple benefits. Thus, a watertight flood shield¹ at a doorway opening can also serve as the door. A raised terrace and gently sloping ramp that furnishes access over a low flood shield at the doorway of a store can also provide a view of the entire sales floor as one enters.

From the standpoint of readiness, permanent measures are preferable to any other, and should be incorporated into a flood proofing program to the greatest degree practicable. In many cases, permanent flood proofing does not require an advance flood warning or the availability of special personnel and it provides the greatest measure of safety by reducing the element of human error. Because of the possibility of unforeseen failure, trained personnel should be on hand in the event of an emergency. At some buildings it may be possible to make many permanent changes while at others few will be possible, if any.

Contingent or Standby Measures. - In many buildings it is necessary to maintain access into structures at points below selected flood protection levels. In addition, display win-

¹ A flood shield is a metal plate of aluminum or steel, a fabricated "gate," a wooden plank or any other device that is used to close off building openings to prevent the entry of flood water.

flows at commercial structures must be unblocked to serve their main purpose. These types of openings cannot be permanently flood proofed, but they can be fitted with removable flood shields. The placement and installation of such devices, however, would require several hours. Therefore, a flood warning system would have to be established before such flood proofing measures could become operational.

Many contingent or standby flood proofing devices have relatively long periods of usefulness--for example, the steel or aluminum flood shields. Building remodeling may alter an opening in such a way that its flood shield is no longer useful, however. In such cases, emergency sandbagging or other temporary measures may be needed. The out-moding of protective measures will be less likely if they are made a part of a building's superstructure and can retract into the ceiling above entrances.

Emergency measures.—These are measures which are carried out during an actual flood experience (Figure 6). These measures may be designed to keep water out of buildings, for example, the sandbagging of entrances or the use of planking covered over with polyethylene sheeting. More often they are intended only to protect equipment and stock. A widely used emergency measure is the planned removal of contents to higher locations when a certain flood stage is reached.

Emergency measures have proven to be an effective means of reducing flood losses, particularly where flood warnings are issued several days in advance of the water's arrival. At times, emergency measures can include actual construction. In some cases the lower sections of windows and doors have been bricked shut in anticipation of flooding, on other occasions temporary walls and levees have been built to keep flood waters away from structures. In some instances where it was not possible to prevent the entry of flood waters, machinery has been dismantled and taken to sites above flood stages, and large quantities of stock have been relocated above the reach of flood waters. Emergency measures are generally less effective than permanent or contingent measures because they are more susceptible to carelessness or complacency.

Owners and managers of buildings are cautioned not to undertake piecemeal flood proofing measures such as installing standpipes or barricading entrances and store windows without professional assistance since such measures could worsen the flood damages.



Figure 6.—Emergency Flood Proofing. Heavy planking covered over with polyethylene sheets (see arrow) was used to give emergency protection to this Waterloo, Iowa, plant during the April, 1965, flood on the Cedar River. (Photo by U. S. Army Corps of Engineers.)

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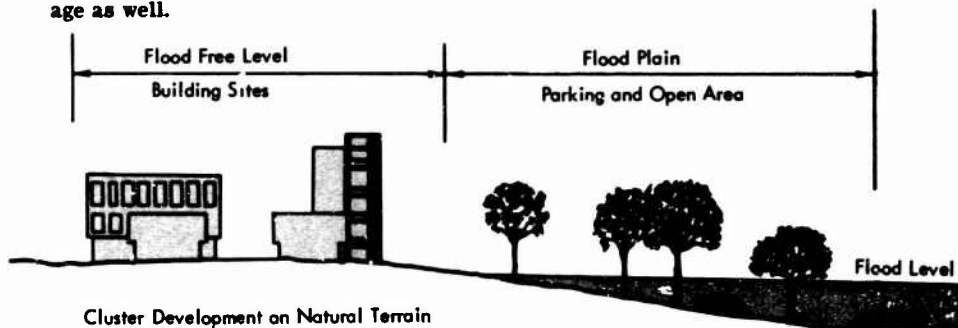
Chapter III. Flood Proofing Procedures

Several general procedures to achieve flood proofing are discussed in this chapter. Some of these procedures, such as laying out sites and raising buildings, are intended primarily for new construction which would represent a proper use of flood plain sites. Other procedures, such as those to keep the water out or those to minimize losses if the water gets in, would apply to both new and existing structures.

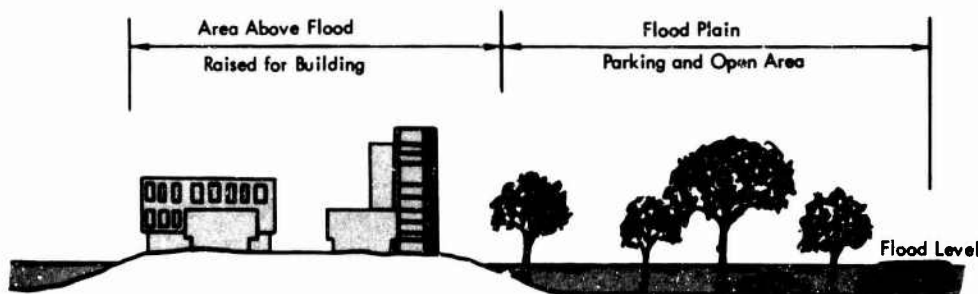
Laying out the Site

The practice of "clustering" buildings is prevalent in planned unit developments. This clustering permits buildings to be attractively grouped on parts of a site which are above flood levels and reserves the low-lying sections as landscaped green areas and parking facilities (Figure 7).

The use of the higher ground for development allows streams and other natural low-land features to be kept intact as scenic elements and fish and wildlife habitats. Many of the natural features of the valley can be made more useful for recreational purposes. For example, low-lying swampy areas can be transformed into permanent lakes that provide opportunities for water oriented recreation and modest amounts of flood water storage as well.



Cluster Development on Natural Terrain



Cluster Development on Artificial Plateau

Figure 7.-A planned unit development on a flood plain site. The example at the top of the page illustrates a valley location with only a part of the site subject to flooding. The lower example shows a site entirely within a pondage area and subject to low stageflooding. In this case, a portion of the site was artificially raised to be above flood levels.

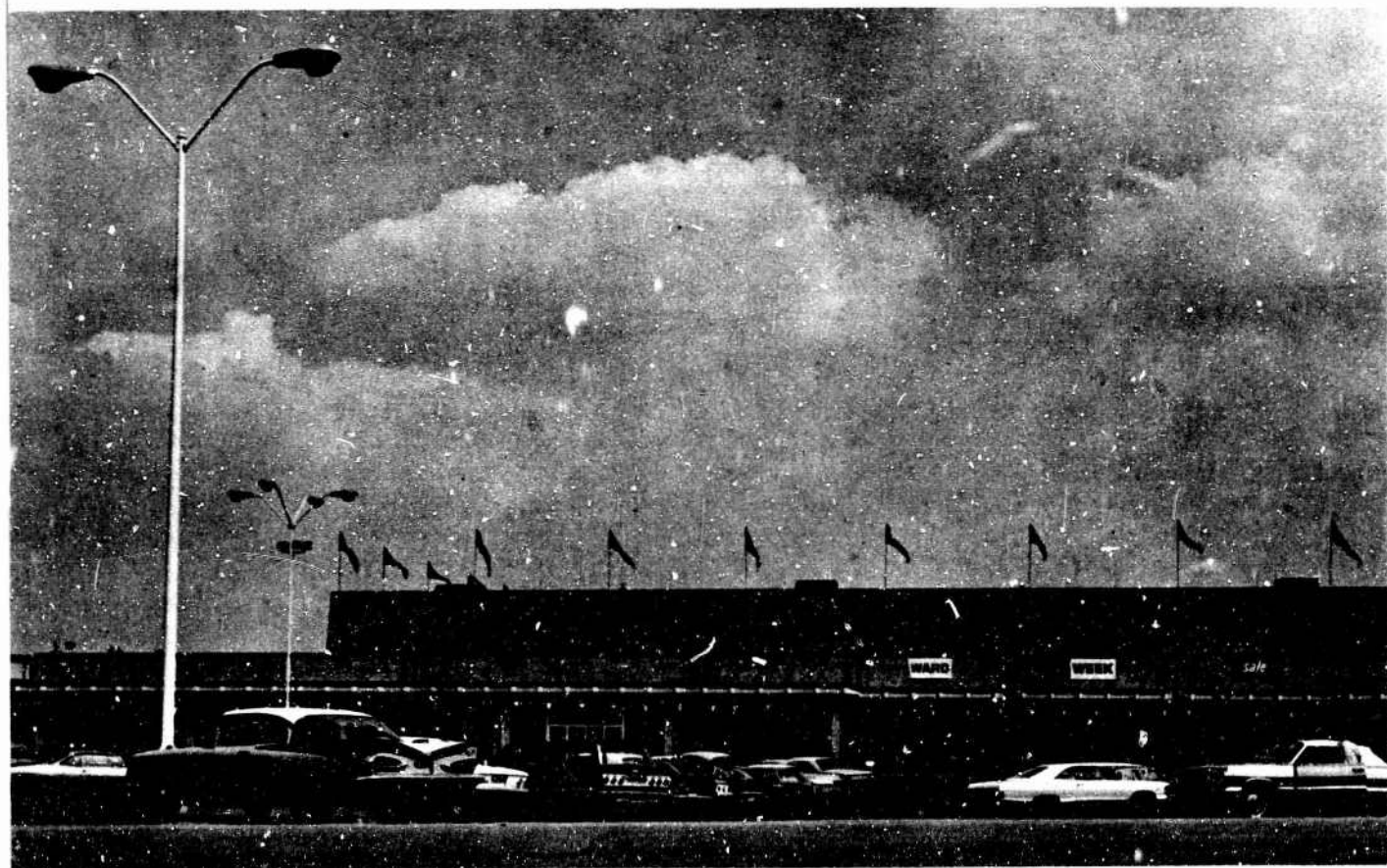


Figure 8.-The Dixie Square Shopping Center in Harvey, Illinois. City officials required floor elevations to be raised about two feet above natural grade because of the flood hazard. Upper photo shows how site has been graded up to the building. Lower photo shows one of the shallow basins in the parking lot designed to temporarily store storm water runoff. (Photos by U. S. Army Corps of Engineers.)

Where natural high ground does not exist, sites can be raised by filling, providing the fill does not interfere with the flow of flood waters. The concept of clustering buildings on higher ground, elevated by filling, is especially useful in metropolitan areas where a shortage of land may force the development of areas subject to low stage flooding.

Figure 8 shows an actual case in which building sites at a shopping center were raised to reduce the flood hazard. The material used for raising the sites was taken from the parking areas thereby creating 26 shallow basins for the detention of storm water runoff. In flood fringe areas, raising the site only a few feet may achieve the desired results--placing the buildings above the design flood stage. Constructing new buildings without basements would facilitate flood proofing of this type since problems associated with ground-water pressure would be avoided.

Flood proofing measures can be designed to blend with the overall appearance of a structure. When this is done, a structure's appearance can be preserved and in some cases even enhanced by flood proofing.

Raising the Buildings

The practice of elevating a building on "stilts" to provide an "open" effect at ground level can also reduce the flood hazard. If some means of access is maintained and utilities can continue to function, activities would not be interrupted during floods.

This raising of the main floor levels is practiced in much new construction throughout the country. There are examples of residential, commercial, recreational, and industrial buildings which have been designed and constructed in this manner. Where land is at a premium, as in central business districts, buildings are often placed on "stilts" with parking facilities on the ground level.

As may be seen in Figure 9, desirable esthetic effects such as the creation of upper level pedestrian plazas above utilitarian lower level parking areas, can be integrated into a flood protective scheme in which the lower level can be flooded without affecting the pedestrian areas and buildings. Similarly, the contemporary practice of placing mechanical equipment on upper levels of multistoried buildings will minimize potential damage of valuable equipment and interruption of service during floods. Techniques designed for the more normal locations can be applied with little modification to buildings in flood plains, and result in structures which will suffer little damage.

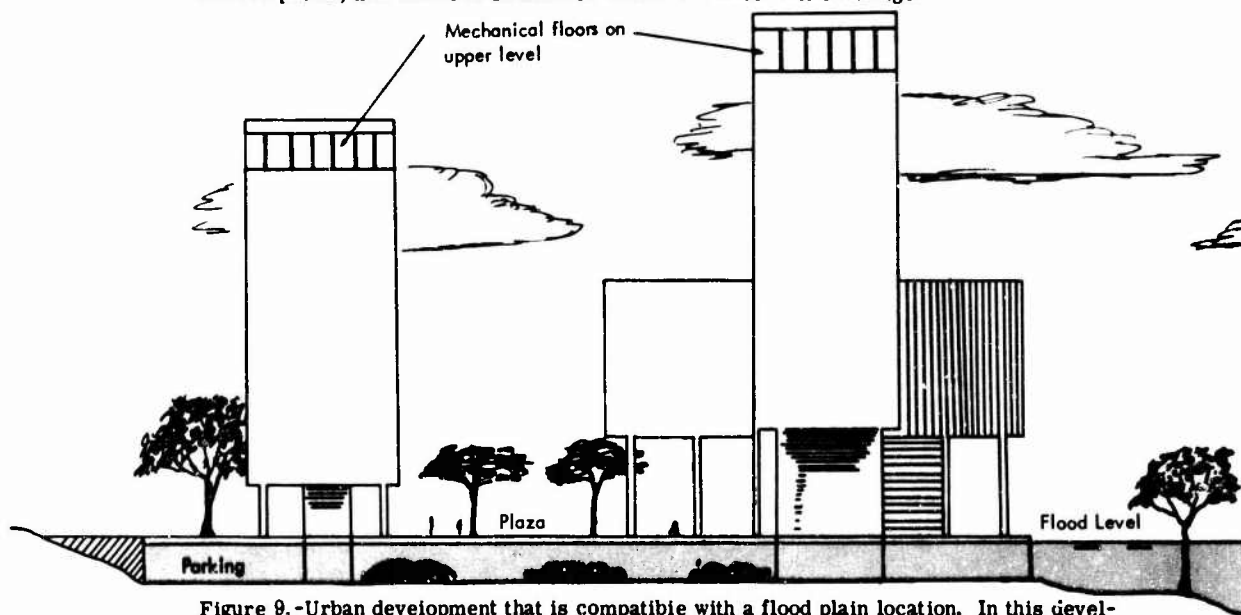


Figure 9.-Urban development that is compatible with a flood plain location. In this development, the uses of the building have been adjusted to avoid uneconomic flood losses.

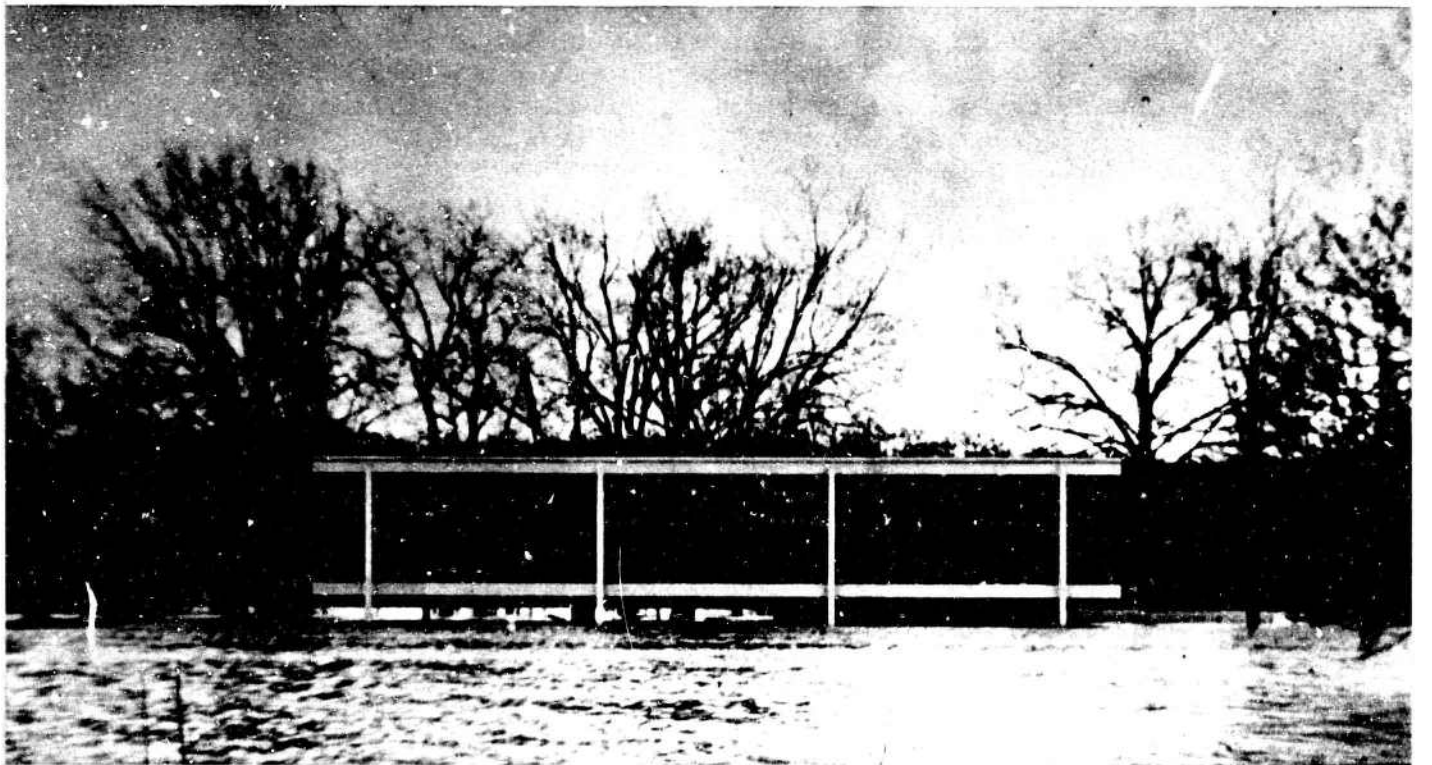
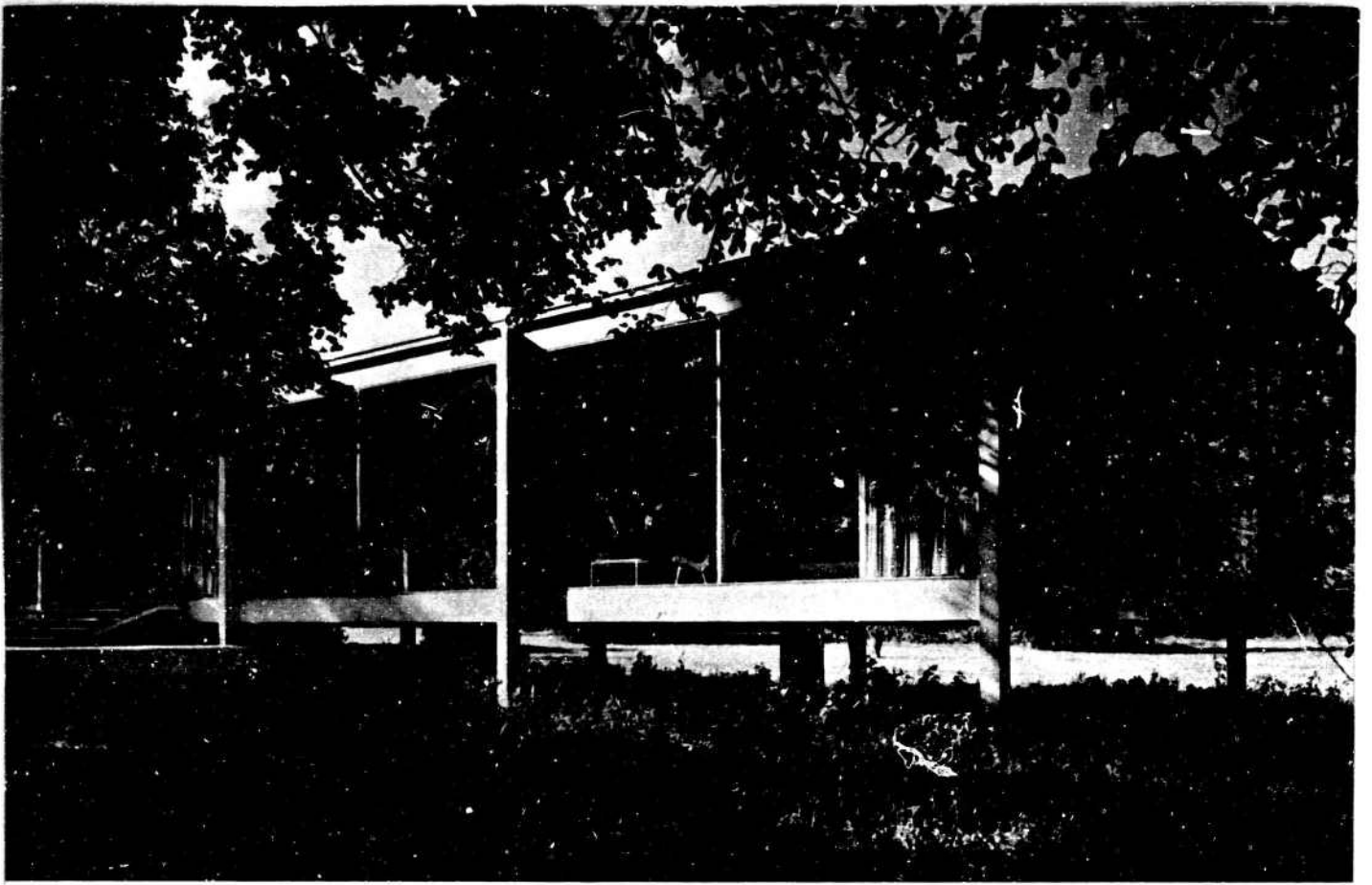


Figure 10.-Farnsworth House, Plano, Illinois. Mies van der Rohe designed this house to avoid damage from Fox River flooding. The lower photograph, taken during the 1960 Fox River flood, shows the success of the design.

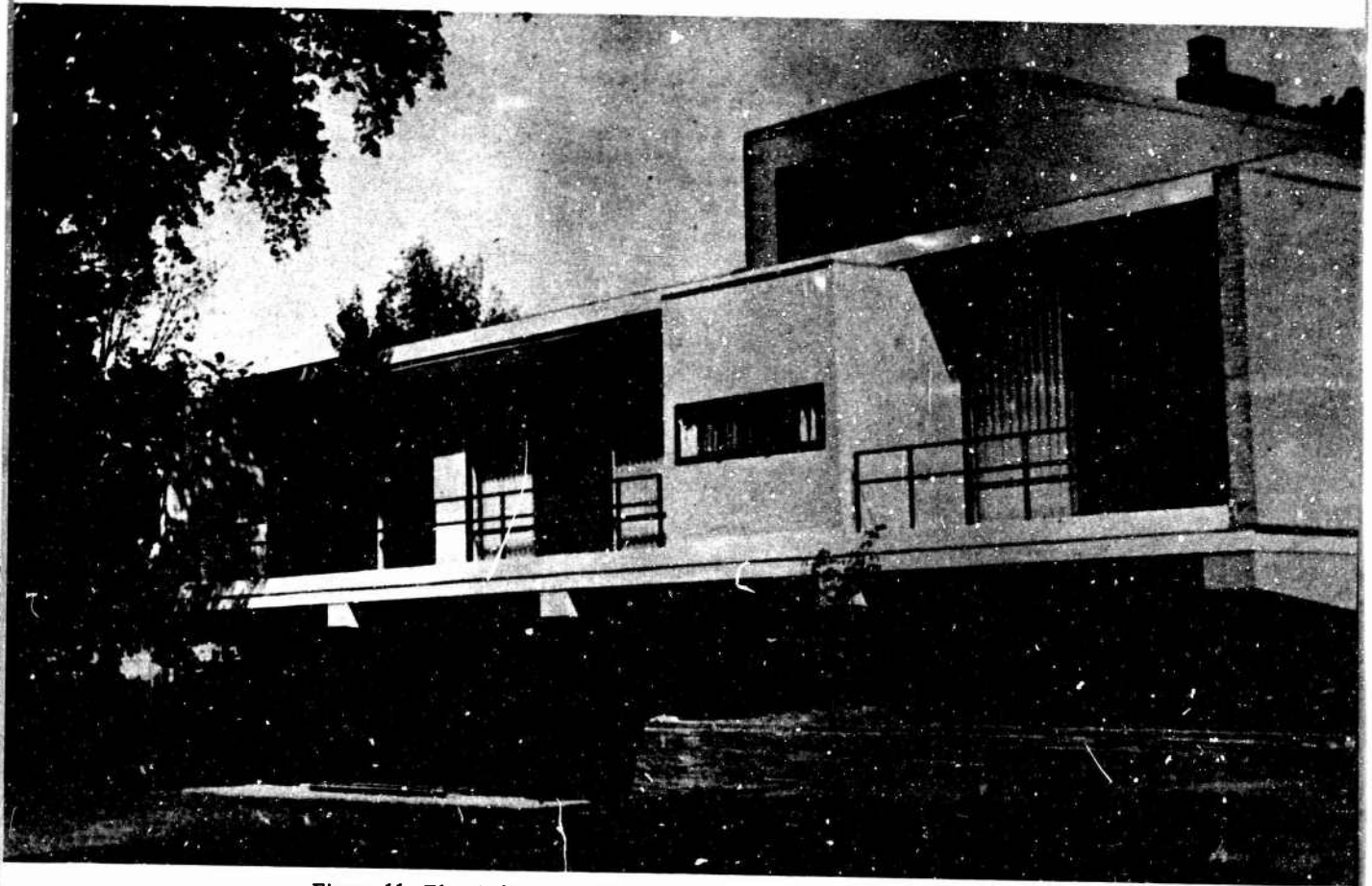


Figure 11.-Elevated houses. The above photographs show two houses of this architectural style. The raised effect can be readily adapted to a flood proofing design. (Photos by D. J. Volk.)

The Farnsworth House in Plano, Illinois (Figure 10), is an example of this approach to flood protection. The house is on the banks of the Fox River and was designed by Meis van der Rohe with the floor level of the home raised on stilts to place it at an elevation above known flood heights. This design was developed to permit the use of a scenic riverfront site for a house location. When the record flood of 1960 occurred, the house proved to be above the flood waters. Figure 11 presents two other houses that demonstrate architectural styles used to elevate houses above flood levels.

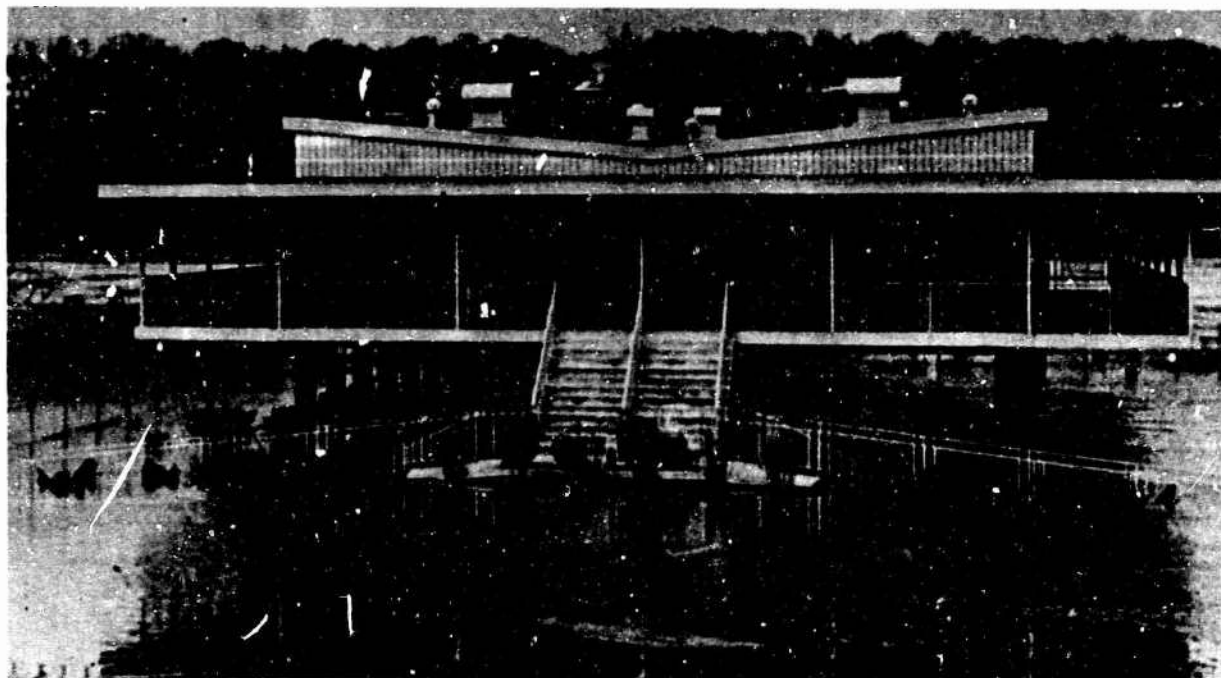


Figure 12.-The Mankier Patten Tennis Center, University of Chattanooga. This building was raised to provide flood protection and to be used as an observation deck. (Photo by Chattanooga Free Press.)

Figure 12 shows another type of building elevated on stilts. The floor elevation of the Mankier Patten Tennis Center, at the University of Chattanooga, is approximately one foot above the maximum known flood as regulated by the TVA reservoir system. The floor was placed at this elevation to reduce flood risk and to serve as an observation deck. The picture was taken when the flood of March 14, 1963, was 0.3 foot below its crest.

Keeping the Water Out

The design techniques discussed above either achieve flood proofing through site planning and development or incorporate flood proofing in the initial construction of the buildings. The location and environment of structures in built-up urban areas may make these solutions impractical. In such circumstances, the building owner, architect, or engineer is faced with a job of designing flood proofing measures for existing conventional buildings which are exposed to flood water. These flood proofed buildings can incorporate many contemporary design features such as large window areas, pedestrian arcades, open floor space and curtain wall panels.

An example of successful flood proofing after construction is the Stanley House in LaGrange, Illinois (Figure 13). The house is located on a scenic site overlooking a golf course. After an experience with high water, the owner constructed a brick wall to close off the front and back porch areas, and added aluminum flood shields to close off the entrance ways. The owner, an artist, says the additions have not detracted from the home's

Mr. Joan R. Sheaffer
The University of Chicago
The Center for Urban Studies
5848 S. University Avenue
Chicago, Illinois

13 Nov. '66

Dear Mr. Sheaffer:

I am pleased to pass on to someone with similar problems any information concerning my flood proofing techniques. I know how upsetting it can be to see one's house flooded.

Our home is a one story brick house, built on a concrete slab. It has recessed front and back porches and a back door near the garage.

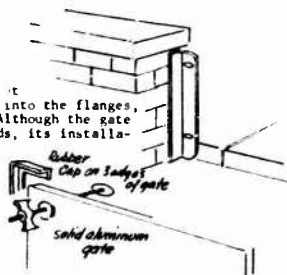
There is a single door in the front, but there are two sets of French doors leading to the back porch.



During our first flood, I found that dirt shoveled in front of our doors did a fair job of holding back all but a small amount of water. But that was a temporary expedient which lead to the more permanent measures described below.

First, we built a 2 1/2 foot high, reinforced, brick wall across the lengths of the front and back porches. A 3 foot wide gap was left for a gate in the front wall. A flange was then cemented to the wall on each side of the entrance gap.

The gate is a 1 inch thick slab of aluminum with 4 easy to tighten bolts put through it for fastening the gate to the flanges. The sides of the bolts were filed down to an elliptical shape so that they could be inserted into the flanges, turned, and caught. Although the gate weighs about 70 pounds, its installation is not too hard and takes only a few minutes. The back door has a duplicate set-up, except that the flanges are fastened directly to the door frame.



Fortunately, we have only had one chance to test the walls and the gates, and they worked perfectly. The water began to rise while I was on a business trip to New York, but my wife and a neighbor were able to install the gates quickly. And, although the water rose to at least two feet above our floor level, the interior of the house remained completely dry. Since the village seemingly solved the flood problem by cleaning and repairing the storm sewers, it has been many years since we have even put in the gates. But we still have them.

In addition, we have a sump pump to drain any seepage into the well to which the hot air ducts are connected. The ducts run under the concrete slab to the registers in the walls. Obviously, there is seepage into the well during a flood that lasts several hours.

We, of course, had the house carefully checked for any cracks or openings between the brick walls and the concrete base.

The whole installation cost less than \$1000. Although I have never had a monetary loss because of my insurance, this device has brought peace of mind worth its cost. I would like to add that, because I am an artist and deeply concerned about the appearance of the house, the addition of the walls and gates has not detracted from the beauty of the house in any way.

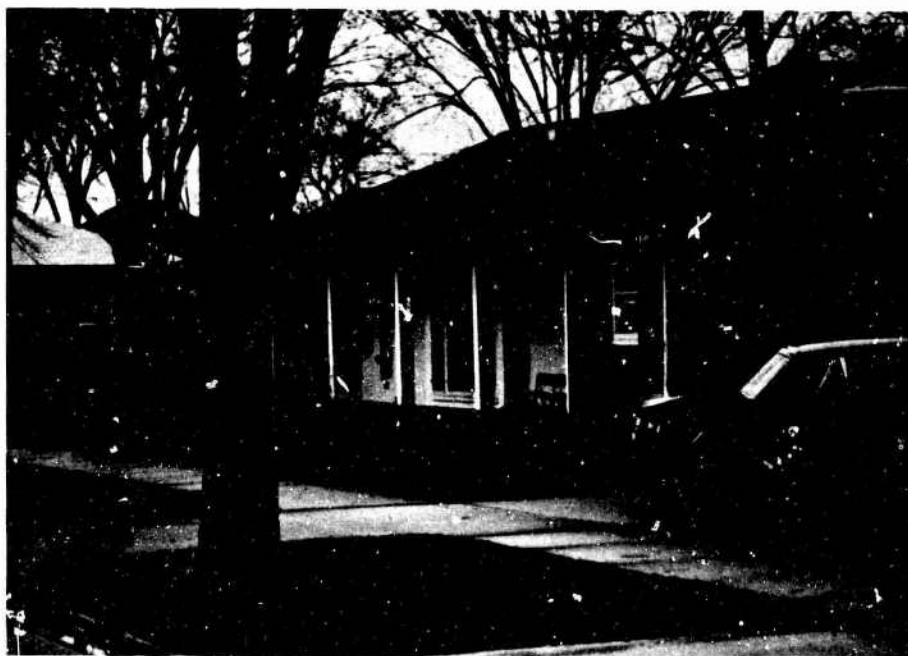
I have no photographs of the installation. But, if you feel it would help you, I would be glad to take some for you.

Let me know if I can be of any more help to you.

Yours,

E. Lee Stanley

Figure 13.-Letter from E. Lee Stanley. This letter from Mr. Stanley outlines the flood proofing measures he undertook, their cost, their success, and the peace of mind he now enjoys. The insert is a photograph of his house as flood proofed.



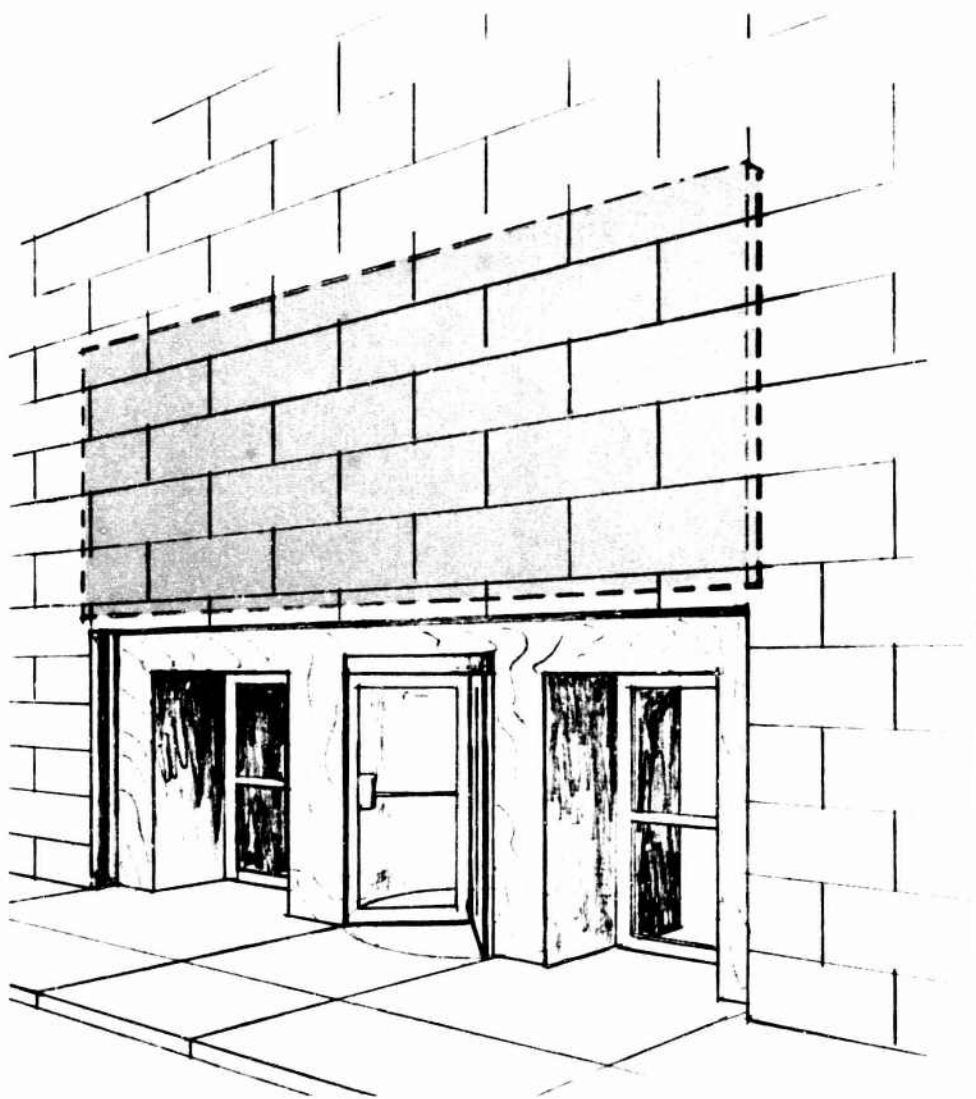
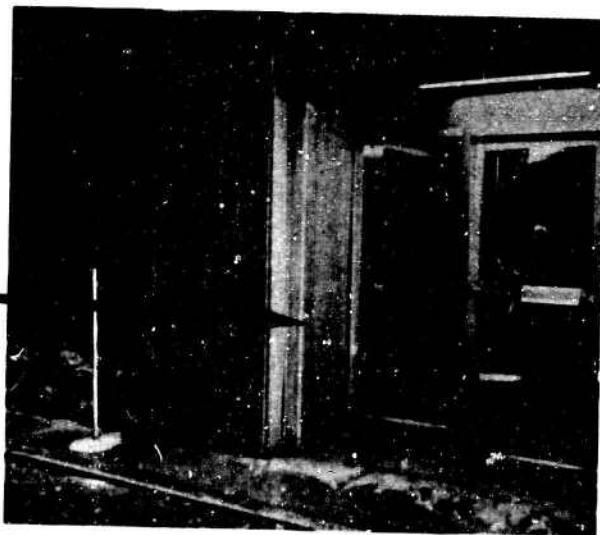


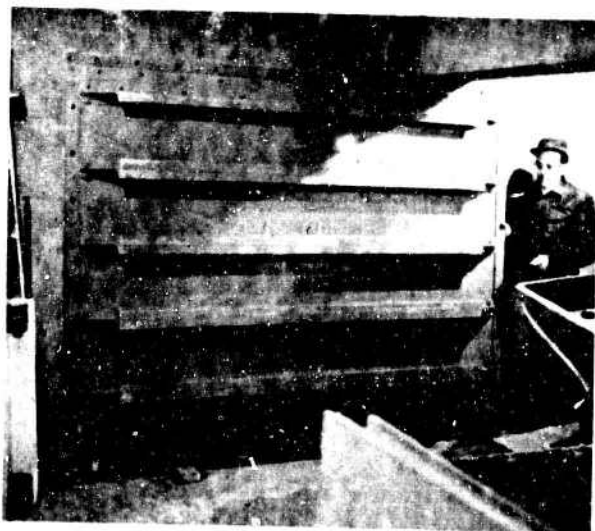
Figure 14. - Overhead flood shield that is in place for testing. This sketch shows how the shield retracts above the entrance. (Photo by Horne Department Store, Pittsburgh, Pennsylvania.)



Remodeled store entrance incorporating glass doors and aluminum sheeting in the design.



Bracket for flood shield covered with removable trim so as not to detract from the appearance.



Flood shield to close off entrance during flooding. The shields are stored in a centrally located flood room.

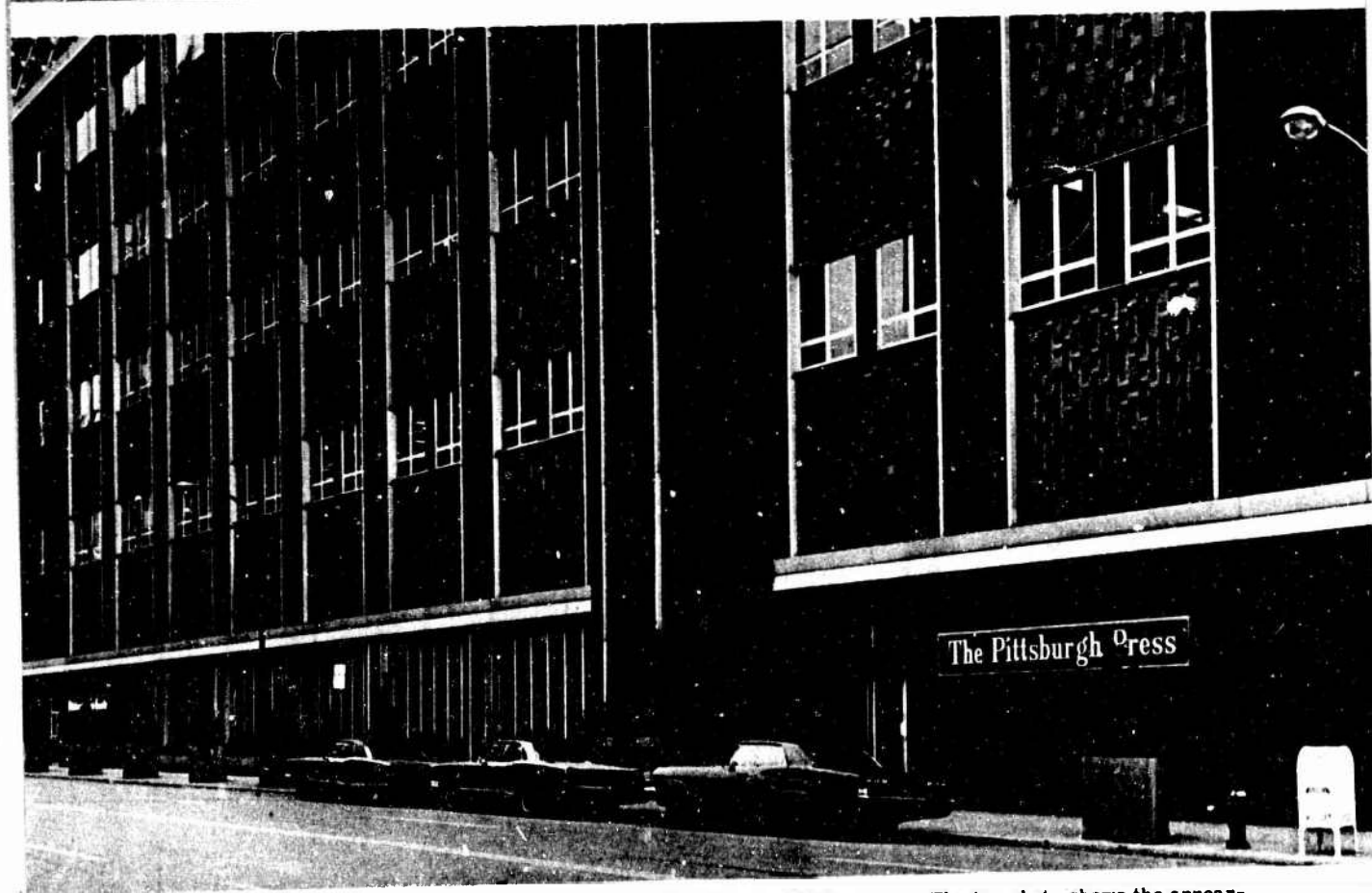
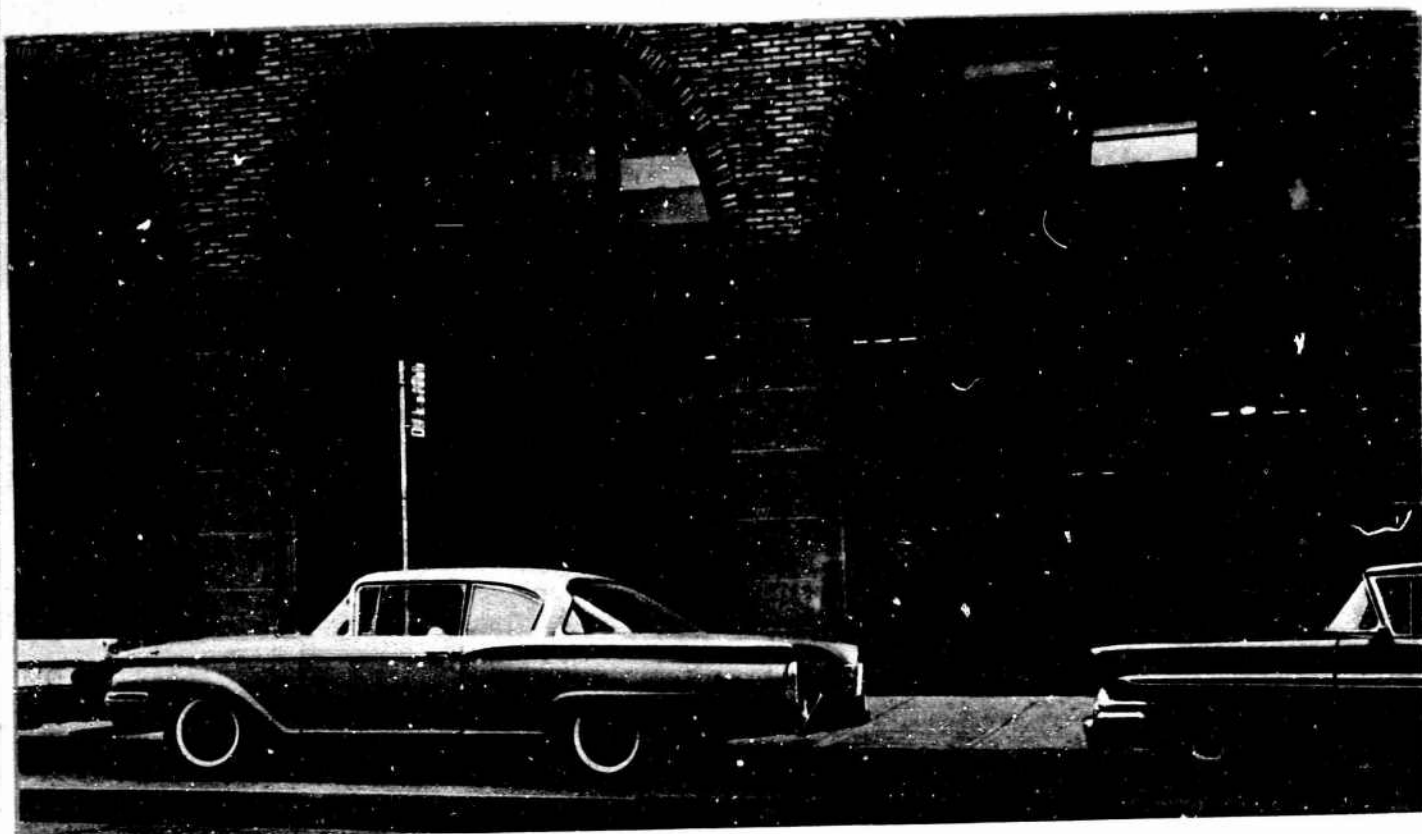


Figure 16.-Flood proofing at Pittsburgh Press Building. The top photo shows the appearance of initial flood proofing. The lower photo shows how the "face lifting" blended the flood proofed windows into the building design. (Photos by Pittsburgh Press.)

appearance and have kept the house completely dry when there was water two feet deep all around it. Further details of the Stanley House are considered in Chapter V, on "Programs of Flood Proofing."

In designing new structures, or in altering existing ones, thought should be given to the use of receding flood shields (Figure 14) which are normally hidden from view, but can be easily lowered or slid into place upon the receipt of a flood warning. Such shields also escape the danger of being misplaced.

When flood shields must be mounted on the street side of an opening, the brackets to which they would be bolted can be concealed with easily removed aluminum strips or "skins." Figure 15 shows a department store entrance that has been modernized and flood proofed at the same time. (The installation required for mounting the shield is indistinguishable from the building trim.)

While flood proofing measures must be functionally able to protect against a selected flood condition, such measures need not detract from the appearance of the structures. When the Pittsburgh Press Building was flood proofed, as an aftermath of the 1936 flood, the alterations transformed the outer appearance of the building. The large plate glass windows were replaced with many small windows of "unbreakable" glass that were embedded in reinforced frames. However, a recent face lifting of the building has made the flood proofing measures much less evident. Figure 16 shows how the initial flood proofing looked and how its appearance was subsequently altered.

Internal Flood Proofing Measures

Owners of buildings which are subject to flood but cannot be easily altered to keep the water out, can consider the use of water resistant construction materials to reduce flood damage. Even owners of flood proofed structures generally able to withstand flooding would also be well advised to consider the use of such materials to reduce losses when flooding exceeds the protection level.

The property owner and his architect can substantially reduce the potential flood damage to a building through the careful selection of water resistant materials. Many such materials are priced in the same range with the more vulnerable materials, but may be worth considering even when their use would mean higher material costs.

Examples are exterior grade plywoods and tempered hard boards in lieu of ordinary construction grade plywood and hard board. These materials can be utilized at a reasonable additional cost and under some conditions substantially reduce water damage. Also, in flood plains a waterproof plaster on galvanized wire lath could prove to be a more prudent long-term investment than gypsum board products which would have to be replaced after a flood. Metal windows, doors and door jambs which would not deform or warp when soaked may also be economical for buildings in flood plains.

In structures subject to flooding, all adhesives used to fasten floor tiles, wall panels and ceiling tiles, should be waterproof so that the adhesive will not fail when wet. Carpeting should be used which can be cleaned without any appreciable damage or evidence of mildew after inundation. Wall and floor surfaces should be finished in a manner permitting cleaning or hosing after a flood with a minimum of damage and deterioration.

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Chapter IV. Structural Engineering Aspects of Flood Proofing

Flood proofing efforts to keep the water out of buildings fall, in part, within the province of the structural engineer. When flood waters surround a building, they impose loads on the structure and substructure beyond those it normally is designed to withstand. A determination of these loads is a prerequisite of flood proofing efforts.

This chapter discusses some of the more common structural problems that could be encountered. Because of the complexity of these problems, building owners who are contemplating flood proofing should engage the service of a professional engineer who has a working knowledge of structures and who has had experience with hydraulic structures or flood proofing. This is necessary to insure that the flood proofing does not increase damages by creating structural damages--ruptured walls and floors--in addition to the damages resulting from water contact and disruption.

Analyzing the Structural Problem

The forces which would act upon a typical building under conditions varying from normal (non-flood) to partial submergence (flood with and without subsurface or foundation drainage) are graphically presented in Figures 17, 18, and 19. The building cross-section shown is considered representative of that which would be commonly encountered in a flood proofing program.

Loading from Structure and Contents.-The weight of the building itself (masonry, concrete, steel, wood, etc.), known as dead load, together with the weight of its live load (furniture, machinery, merchandise, occupants, etc.) will normally be transmitted through the roof and floor systems to supporting columns and walls and thence to the foundations. These loads generally are transmitted directly to the supporting soil or bedrock under the foundation. Loads of this type will normally be unaffected by flooding and will have the same value for both flood and non-flood conditions.

Restraint from Floor and Roof Systems.-Flooding produces large lateral forces on the structure. These forces will be resisted by the building walls, floor, and roof systems. Many commercial and industrial buildings are designed and constructed in a manner to provide adequate connection and anchorage between these systems for support and structural unity, but each building must be individually evaluated and strengthened where necessary.

Most residential and many light commercial and industrial buildings, however, do not have the necessary anchorage and would require modification to provide it. This would involve adequate transverse bridging in addition to anchorage into the walls around the entire perimeter. Steel angles bolted into both the floor system and the walls at their juncture would be one method of anchorage.

Resultant of Non-Flood and Flood Loading.-The non-flood loading is the force exerted by the soil backfill upon the wall. These pressures depend upon the physical characteristics of the soil particles, the degree of compaction, the moisture content, and the move-

ment of the wall caused by the backfill and foundation deformation, if any. Where the top of the zone of saturation (water table) is at an elevation above the base of the foundation, the pressure on the wall and floor slab is due to the buoyant weight of the soil plus the full hydrostatic pressure of the water. When a workable subdrainage system is provided to lower the elevation of the water table, the pressure on the wall will be reduced. The degree to which the water table can be lowered will depend upon the permeability of the soil and the efficiency of the subdrainage system.

Flood loading without subdrainage is the force of the full hydrostatic pressure of the water above as well as below the ground line plus the buoyant weight of the soil. As schematically illustrated in Figure 18, the magnitude of this force can be considerably larger than the force developed under nonflood conditions (shown in Figure 18 for comparison).

When subdrainage is provided, this flood loading force is reduced. However, in the case of an existing building with an existing unmodified, subdrainage system, prudence would dictate that no load reduction be assumed. Subdrains, where already installed, are generally provided only to intercept seepage and control uplift on basement floors due to ground water. If such a subdrainage system were to be modified to attain a known degree of effectiveness, a load reduction could be determined. Obviously, for new construction the subdrainage system can be designed and constructed to afford a predetermined degree of reduction of flood loads.

The magnitude of the flood induced forces that will be encountered is indicated by the fact that a one story brick building (3 5/8 inches of brick over wood frame) can be expected to withstand no more than two feet of water above the ground line providing the wall is in good condition. For brick with concrete block backup this height would be somewhat greater.

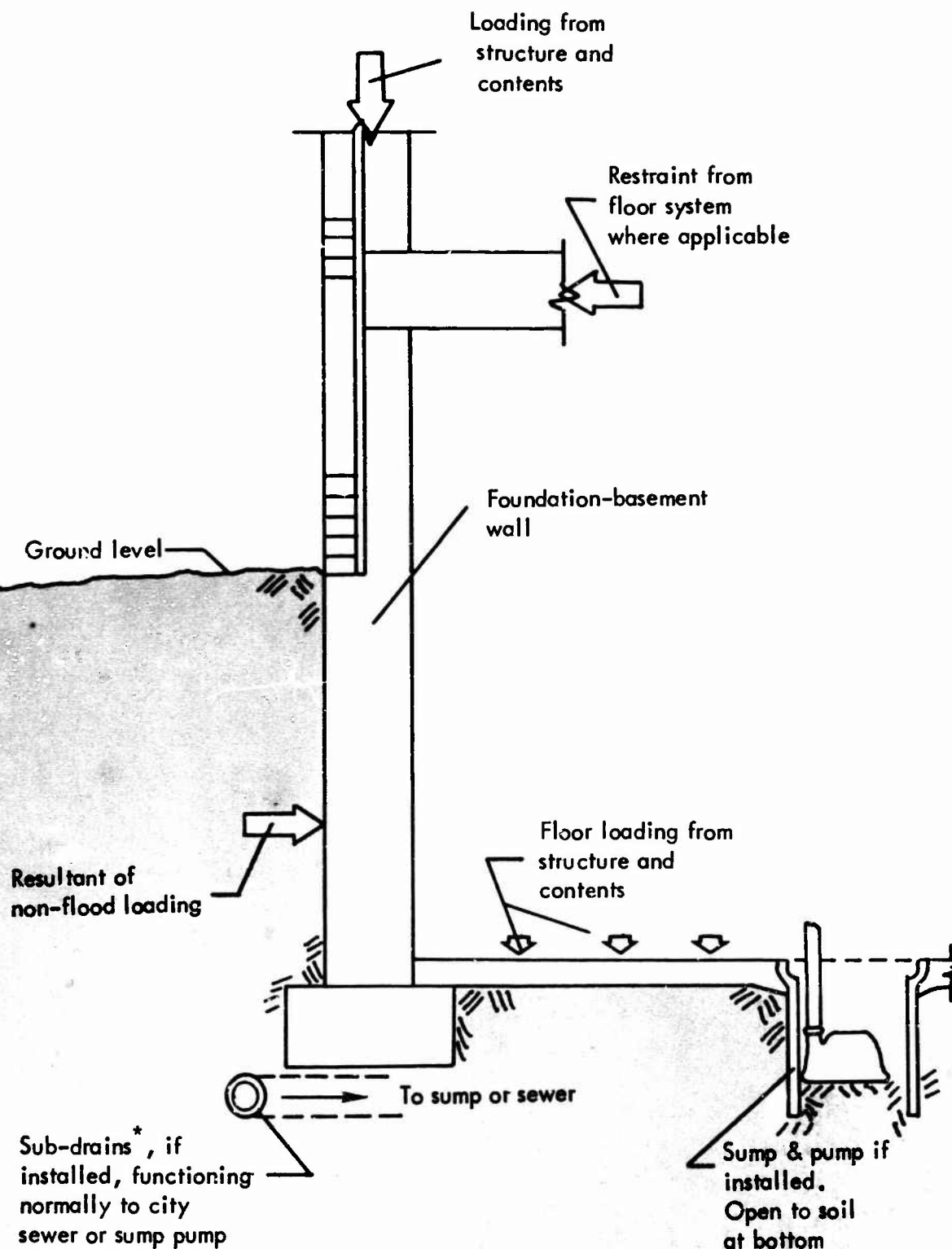
Subsurface Drainage

Ground-water conditions may adversely affect the stability of a building or structure either through uplift which tends to "float" the building or by erosion which can undermine the support. Investigation and analysis of the factors involved at any specific building and the design of control or corrective measures are endeavors requiring the attention of professionally trained personnel.

Ground-water problems can be controlled by the installation of subdrainage systems (see Figures 17 and 19) to reduce the lateral forces on the foundation walls and floor slabs. Experience has shown that the composition of soils in a particular area can vary widely, with extreme ranges of permeability existing in areas of the same general geological origin. Such ranges in permeability argue further for careful investigation and analysis. The design of a subsurface drainage system must be based on the results of soil investigations of permeability and analyses of structural strength.

A sump and pump system can be employed to help protect the subsurface part of a building. The pump could be designed to accept storm and seepage flows and pump them to a point above the flood waters. The sump should be open to the soil at the bottom and to atmospheric pressure at the top within the basement. This would provide a fail-safe feature, in that power or pump failure would allow water to flood the basement and thereby tend to balance the outside flood induced pressures upon the basement walls and floor slab. As an alternative, a prearranged program of deliberate flooding with clean water could be employed to minimize the cost of clean up after a flood.

Seepage Control.—Foundation walls can be made watertight to minimize water infiltration through cracks and crevices in the walls. In buildings under construction, this can be accomplished through the use of waterproof membranes and seals. Construction joints can be protected by the use of a neoprene or other similar waterstop. Existing masonry or stone foundations are more difficult to waterproof, particularly if the mortar joints have deteriorated with age. Sealing of walls to prevent seepage can be



*Existence of subdrains depends upon the requirements of local building codes, ground water conditions, soil conditions, storm or combined sewerage systems if any, etc.

Figure 17.-Typical building loads under normal conditions.

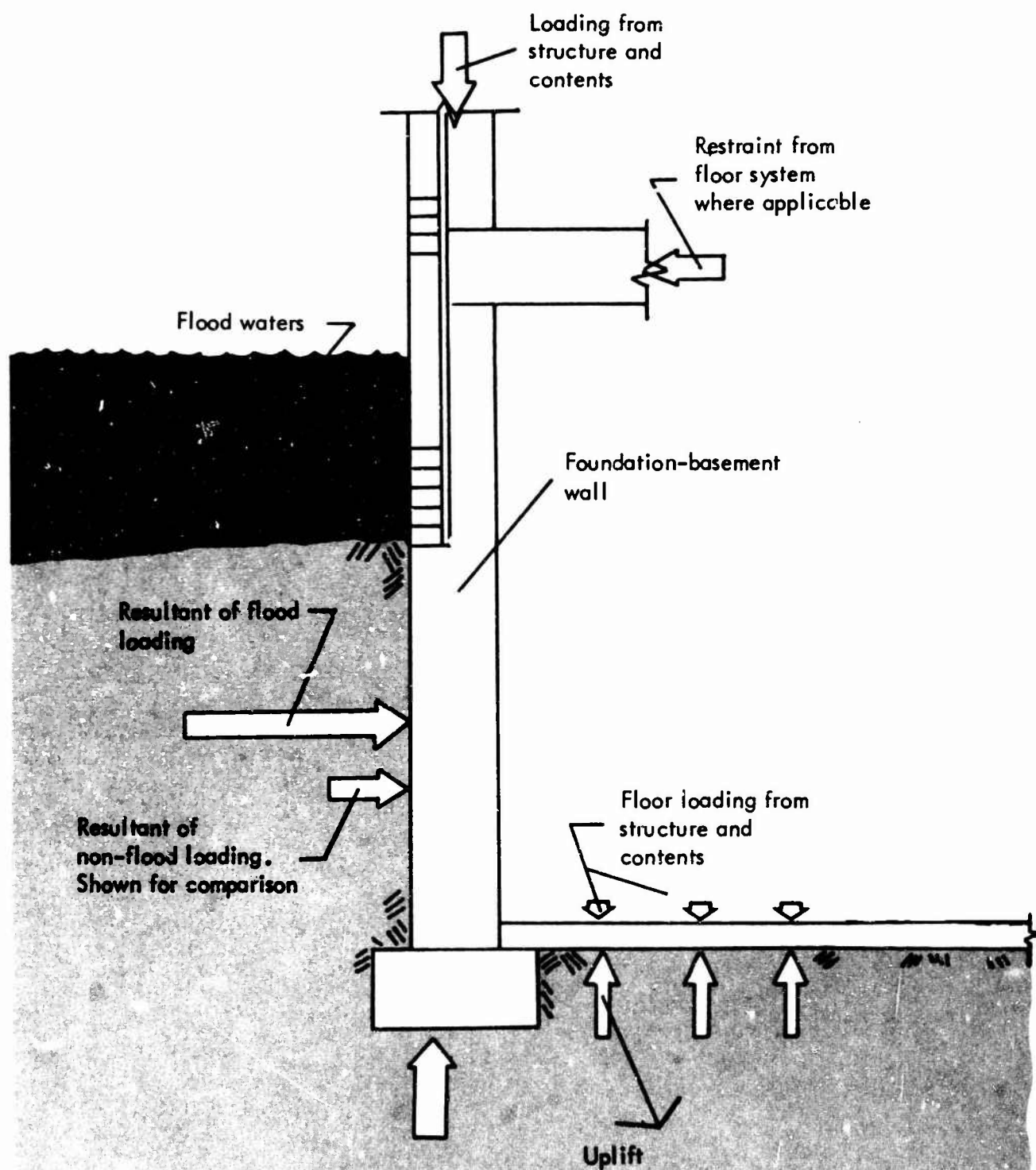


Figure 18.-Typical building loads under flood conditions without subsurface drainage.

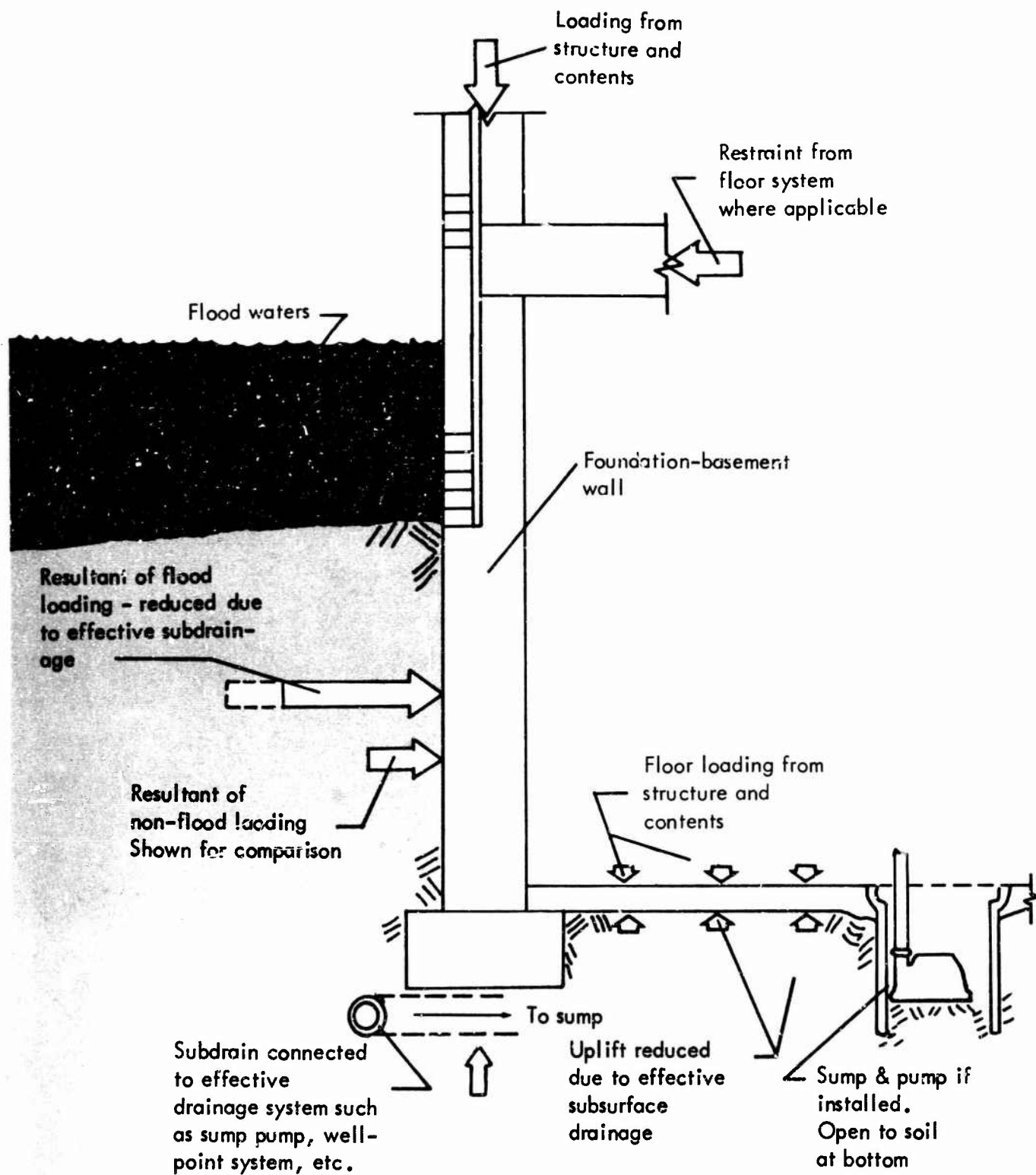


Figure 19.-Typical building loads under flood conditions with subsurface drainage.

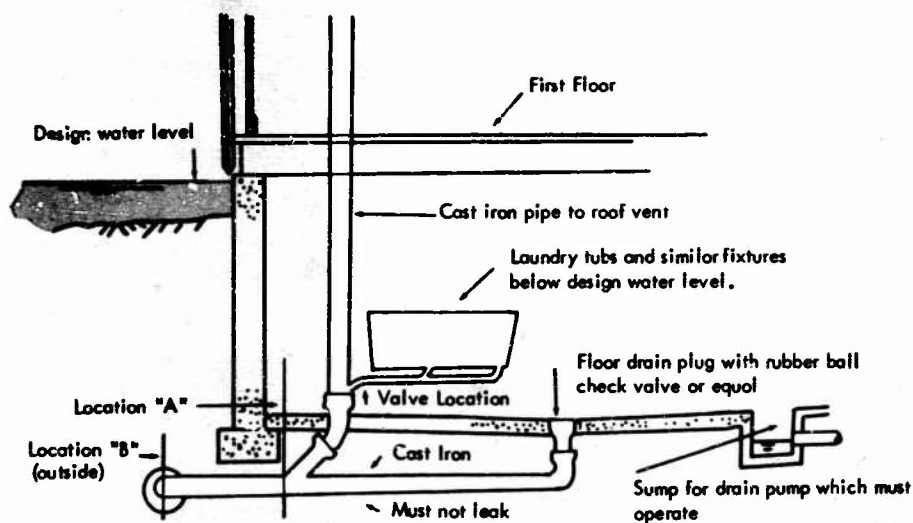


Figure 20.-Alternative locations for cutoff valves on sewer lines.

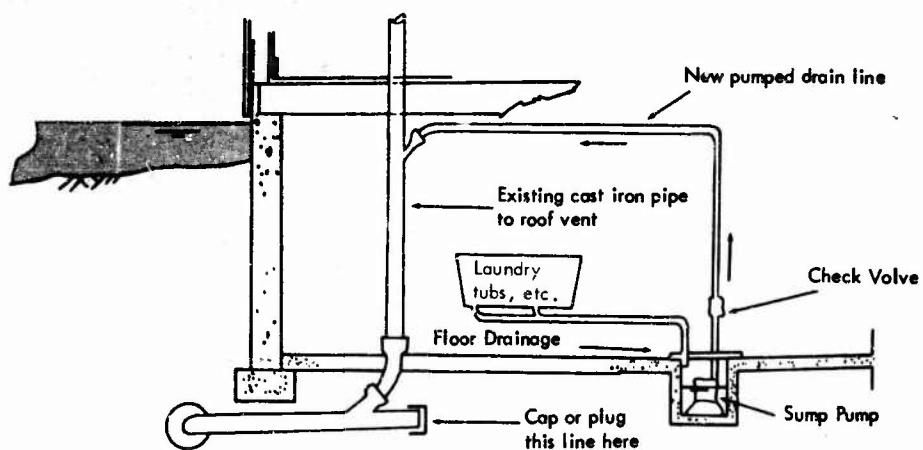


Figure 21.-Elimination of gravity flow basement drains.

accomplished in many cases, however, by coating them, preferably on the exterior, with hydraulic cement, epoxy paint, or other similar waterproofing materials.

It must be recognized that sealing and waterproofing of walls increases the hydraulic forces acting on the walls unless the drainage through the walls which is afforded by the cracks and crevices prior to sealing is provided by other means. Sometimes the wisest course would be to permit the seepage through the wall and then control it by a floor drain and sump pump. Existing cracks and leaks in walls sometimes can be the most practical form of drainage to relieve pressure. In some cases this drainage can be supplemented by holes drilled through the walls. Structural and hydraulic analyses of alternative designs and associated cost estimates will enable the designer to choose the most suitable means of controlling seepage at a given building.

Sewage Backup.—Most existing subdrains, whether connected to sewerage systems or not, are subject to backflow and high pressures during floods. Since these high pressures could burst the usually encountered clay pipe subdrains and endanger basement walls and floors, some device such as a gate valve must be provided for protecting or isolating the subdrains around the building from these high pressures.

There are several alternative methods for controlling backflow through sewers. One method would be to install a main valve at a location where the sewer is strong enough to resist the flood induced pressure and where all possible reverse flows can be stopped. See locations "A" and "B" in Figure 20. This valve should be designed to accommodate grit and other materials which could lodge in it.

If the pipe is of sufficient strength, an alternative would be to install separate valves on all basement fixtures and floor drains (Figure 20). These valves could be inflatable rubber plugs or a similar type of mechanically expandable rubber plug. Valves designed for low pressure (20 psi and less) could be installed in drain lines of fixtures which are below design water levels. In either of the above alternatives, it would be necessary to provide adequate sump pumps to handle any leakage.

Figure 21 presents another alternative for controlling sewer backup. This alternative provides for outletting all floor drainage, appliance drainage, drain tile flow, and any seepage that might enter the building, to a sump pump. The pump would lift the drainage up to an elevation above the design flood on a permanent basis. By thus eliminating all gravity sewer drains, the problem of flooding backflow can be eliminated and a subsurface area permitted to function during floods.

Structural Engineering Observations

The highly technical and thorough nature of the investigations and analyses required in the design of effective, safe, and reliable flood proofing measures for both new and existing facilities cannot be over stressed. Construction of new, or modification of existing subdrainage systems without such investigation and analysis can result in a situation potentially more dangerous to life and property than no flood proofing program at all.

The large number of factors and the potential magnitude of the forces involved make it impossible to design flood proofing measures by intuition. Such an approach can lead to loss of property and even life during a flood, with all the attendant legal problems in addition to the disruption and misery.

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Chapter V. Programs of Flood Proofing

Under the general guidelines discussed in the previous chapters, the flood proofing of each building must be separately examined, since the approach and measures required will differ for each structure. Also, the flood proofing program for a particular building may consist of several types of measures--permanent, contingent, and emergency--as discussed in Chapter II.

A realistic level of protection can be determined when the building owner or manager, his architect and his engineer recognize the nature of the flood situation in their locality, the strengths and weaknesses of the structure, and the condition of the soil under and around the foundation.

The various aspects of a flood proofing program are discussed in this chapter. The illustrations presented are examples of flood proofing measures that have been installed as parts of protection programs for existing buildings.

A Standard Operating Procedure

Any individual or organization undertaking a contingent or emergency protection program must have a standard operating procedure to carry out the flood proofing measures when the need arises. Some buildings can be "buttoned up" in a short time while others may take considerably longer. The time element will depend upon the number of actions involved, the complexity of the program, the number of employees available, their understanding of the program, and their ability to handle assigned tasks. Figure 22 reproduces a portion of the flood proofing procedure which is used by the Pittsburgh Press. Order and advance planning are important factors. Each flood proofing system should have a timetable or check list keyed to flood stages. The call out of manpower and the assigned actions of work crews can follow a mobilization schedule which corresponds to the rise of the flood waters.

The flood proofing system should be designed so that it may be put into operation as quickly and as simply as possible. Flood shields, doors and hatches may have to be handled during the most adverse weather conditions (perhaps during the stormy weather which causes the flood), so lightweight metals should be used wherever possible.

Flood proofing items including bolts, gaskets, caulking, timbers, and flood shields should be stored for easy access. The larger more bulky items should be stored close to the point of insertion and when possible in such a manner that they can be easily slid or dropped into position. One lost or improperly mounted flood shield, or the failure to valve off a sewer, can undo an otherwise perfect plan. Flood shields at the Pittsburgh Press Building have been mounted on the outside walls close to the points where they would be used (Figure 23). As can be seen, a numbering or coding system has been developed so shields can be matched readily to the proper openings. Nuts and bolts for mounting the shields are bagged accordingly.

1. AT FLOOD STAGE OPEN ALL DRAIN VALVES 0-1 THROUGH 0-9 &
2. AT FLOOD STAGE CLOSE ALL DRAIN VALVES C-10 THROUGH C-29 &
3. TRANSFER ALL BASEMENT PAPER STORAGE TO 4TH AND 5TH FLOORS &
4. TRANSFER ALL BATTERY-POWERED LIFT TRUCKS TO 4TH & 5TH FLOORS &
5. RAISE ALL ELEVATOR CABS & PLATFORMS TO 2ND FLOOR LEVEL OR HIGHER.
6. MAINTAIN & REPLACE BROKEN GLASS IN FLOOD WINDOWS.
7. PERIODICALLY OIL & HAND-TURN FLOOD PUMPS.
8. PERIODICALLY START & RUN FOR SHORT PERIOD GASOLINE ENGINE FOR FLOOD PUMPS.
9. AT 6' BELOW FLOOD STAGE INSPECT RING NETWORK BUSS VAULT FOR ENTRANCE OF WATER THROUGH CONDUIT INTO VAULT &
10. INSPECT ALL TRANSFORMER VAULT SERVICE ENTRANCES INTO BUILDING FOR WATER LEAKS.
11. DURING ENTIRE STAGE OF HIGH WATER INSPECT BASEMENT EXTERIOR WALLS FOR CRACKS & BOILER ROOM FOR LEAKS IN WALLS & FLOOR.
12. AT FLOOD READINGS SHOWN ON OPENING ELEVATION SCHEDULE THE OPENINGS SHALL BE SEALED IN THE FOLLOWING SEQUENCE:
13. FIRST, SAND-BAG POST-GAZETTE & PRESS ENTRANCES AS PER DETAILS ON THIS SHEET.
14. SECOND, INSTALL SHUTTERS D-3, D-10, D-12, D-13. & D-1, D-4, D-5, D-7.
15. THIRD, INSTALL SHUTTER D-2, D-9, D-11.
16. FOURTH, INSTALL FLOOR COVERS 0-1 & 0-2.
17. FIFTH, INSTALL SHUTTERS D-6, D-8, A-1.
18. SIXTH, CAULK PAPER LIFT DOORS.
19. SEVENTH, INSTALL POSTS & WEDGE SECURELY TO BEAM AT BASEMENT CEILING IN PRESS WASHROOM.

Figure 22.-Flood proofing procedure, Pittsburgh Press Building. This step by step plan of action is necessary to carry out effectively the flood proofing program.



Figure 23.-Flood shields stored on outside wall. These large steel flood shields are mounted on the outside wall of the Pittsburgh Press Building adjacent to the openings they are designed to close. When flood occurs, these shields are placed over the openings and bolted into place. (Photo by Pittsburgh Press.)

Maintaining a State of Readiness

In addition to the development of an actual flood proofing program, a procedure must be developed to maintain a state of readiness. One technique to keep flood proofing measures operational is periodic testing. In Pittsburgh, for example, the Horne Company's insurance firm formerly required that once a year the flood shields which protect window, door, and other openings be put in place and sealed, just as they would be during the time of a flood (see Figure 14). This requirement has now been waived and instead the insurance company requires a thorough annual check of the state of readiness of each item in the program. A company flood manual is used to acquaint personnel with area flood problems and to outline specific tasks to be performed should an emergency arise.

Complacency can be the ruin of any flood proofing program. The longer the interval between floods, the greater the feeling that "it can't happen again." Long flood-free periods tend to dull the awareness of the need for flood proofing.

A check of management readiness is almost as important as the examination of the physical elements of the system. If management becomes complacent, this complacency will be reflected in the attitudes of employees and the system will develop serious gaps as time progresses. As new employees replace older ones, the flood problems move from the realm of personal experience to hearsay. This can be guarded against with employee education, assigned duties and perhaps even flood proofing drills.

The Subsurface Part of the Building

Newly designed buildings may have machinery located on upper floors but most older structures have the electrical machinery, the heating and the pumping equipment on lower floors. It is these lower, subsurface floors, which first experience flooding problems from seepage and sewer backup. Since flood proofing systems often require pumps, electrical equipment and emergency generators as an essential part of the operation--these must be kept in working condition throughout the crisis.

When buildings have entrances to subsurface levels which lead out onto ground level, these entrances should be adjusted to prevent the entry of overland flow. Figure 24 shows how a stairway opening could be flood proofed by encasing the entrance with a concrete block wall treated with asphalt and installing a watertight bulkhead door. To increase the strength of such a wall, the block cells could be filled with concrete and steel reinforcing rods. The two photographs in Figure 24 are existing examples of this technique in use. One of the installations in this figure is a part of the flood proofing program at the Chicago Union Station which was initiated as an aftermath of the 1954 flood which inundated the station.

Several buildings subject to flood have installed low protection walls around furnaces, air-conditioners and other valuable equipment (Figure 25), to protect the equipment if water accumulates in the basement. This approach may prove most desirable when the basement floor is not adequate to withstand hydrostatic pressure, so that flooding to a few feet is allowed to prevent the floor from cracking or rupturing by equalizing the pressure. In some cases pumps are operated from the "safe" islands to control the water depth in the other parts of the deliberately flooded basement. Only enough water is allowed in the basement to prevent structural damage.

An alternate method of protecting valuable equipment would be to "mothball" it by applying a coating of grease, by spraying with parafin or plastic, or by enclosure in water-proof polyethylene or vinyl film. Equipment so protected can be submerged for considerable periods and later put back in operation with a minimum of expense compared to the cost of restoring unprotected equipment.

When none of the above measures is possible, or in the case of an emergency, it is suggested that the motors, other vital electrical relay components and mechanical equipment be removed and stored above flood level. Even if this cannot be done, much of this equipment can be restored to working condition by proper salvage even if inundated. Salvage of equipment and materials can be another method of reducing flood loss. The goal of flood proofing is loss reduction, however it is accomplished.

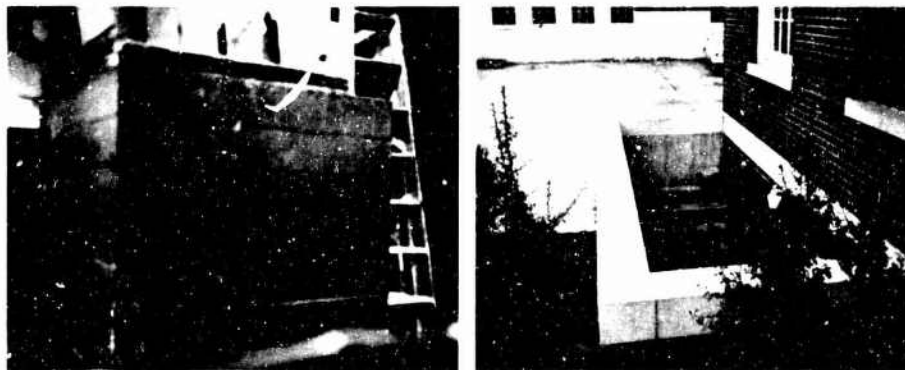


Figure 24.-Flood proofing to prevent overland flow from entering subsurface levels. These photographs are examples of walls which have been built around openings which lead from above the ground level to subsurface levels of buildings. Until these flood proofing measures were undertaken, flood waters flowing on the surface would enter through these openings and inundate the lower levels. (Photo on right by TVA.)

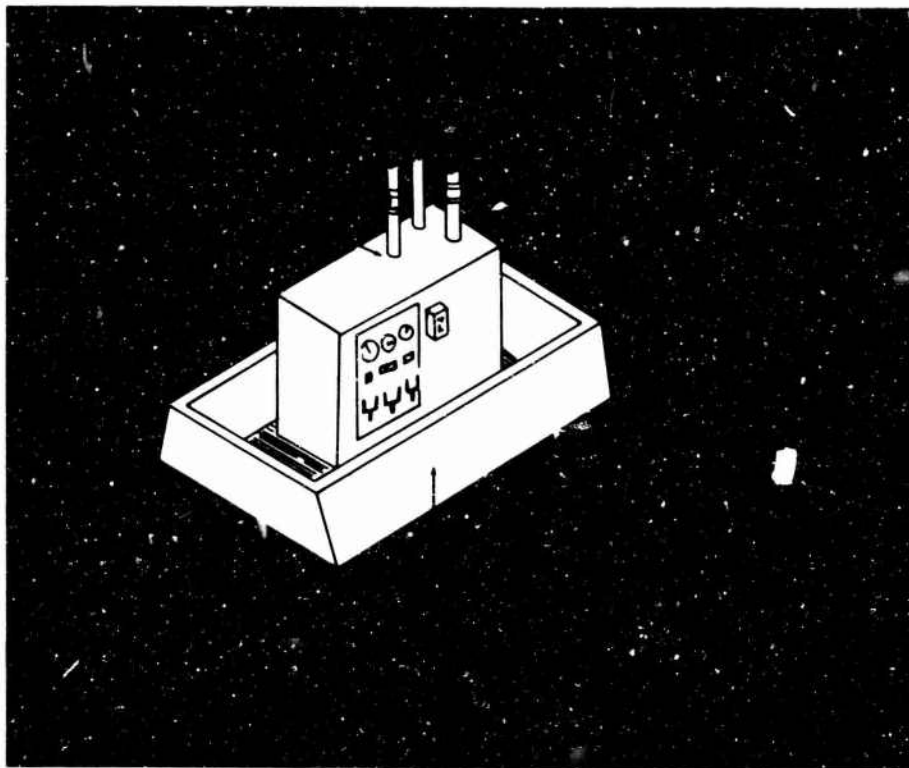


Figure 25.-Protection of Mechanical Equipment. This wall was constructed to protect vital equipment from low stage flooding.

Termination of Utilities

When flood proofing a building, provision should be made to eliminate the threat of flooding by way of gas mains, sewers, conveyor systems and water pipes or drain tiles which enter the building. Gate valves or one-way swing valves can be installed in utility pipes to provide protection against the threat of this source of flooding. Figures 20 and 21, in Chapter IV suggest locations for valves to shut off sewer lines. Figure 26 illustrates several types of valves that could be used for such purposes.

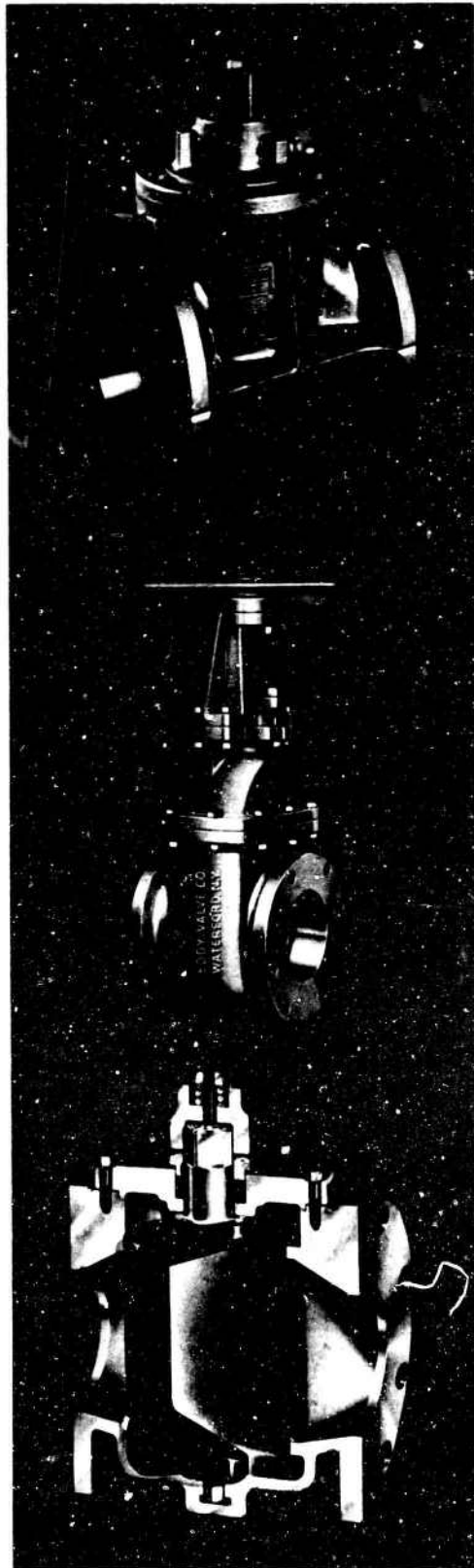
Vitrified clay pipe should not be used within the confines of building walls, and they should never be located next to an entry valve. If sewers are to be valved off they should be cast iron, steel, or reinforced concrete. Otherwise the pressure built up in the line could cause a rupture.

Fuses and circuit breakers servicing flooded building areas should be clearly marked and easily accessible. Electrical circuits serving lower building levels should be designed or modified so that they can be cut off if flooding begins. This will protect against fires and loss of life due to electrical shocks. As another precaution, valuable electrical appliances which cannot be moved should be disconnected at the unit to prevent short circuiting and damage to their power components.

Continuation of the Building Systems

Unless a building is to be completely evacuated during a flood, provision should be made for continuing essential building systems at least on a limited basis. First consideration should go to locating central telephone equipment and electrical transformers above

Figure 26. -Cutoff Valves for Sewers.
These types of valves can be used to
control the problem of flooding
from sewer backup.



flood level. In addition, auxiliary generators should be available to provide energy during a power failure for temporary lights, vital pumps to control seepage, and elevator operation.

Sewer systems can be kept in operation through the use of shut off valves to prevent backup and the installation of pumps. The same pumps can also remove seepage from the building if outlets are provided which extend above known flood stages. Check valves, vacuum breakers or air gaps should be installed to prevent back siphoning.

Water mains normally are kept under sufficient pressure to avoid contamination by flood waters. Pressure should be increased during floods, however, to compensate for the increased head acting on the mains. If the pumping station is flooded, however, pressure will be reduced and contamination can occur. This suggests an internal water supply, perhaps a roof storage tank, to keep buildings in operation during floods. It is also advisable to provide cutoff valves to isolate any portion of a building which may be flooded to prevent contamination by back siphonage into those parts which are not inundated. Where water wells are located on flood plains, their casings should be sealed and extended above anticipated flood levels to prevent the entry of polluted flood waters.

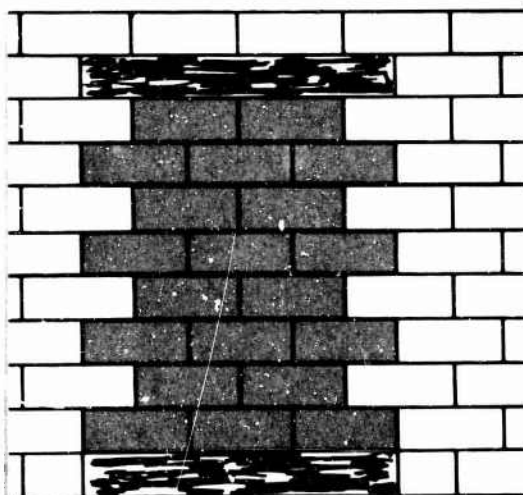
Storage tanks may contain products necessary for a building's operation. They should be anchored and weighted down or else raised above flood levels to prevent flotation and loss during floods.

Closing Wall Openings and Vents

Windows and vents both above and below the surface should be sealed to prevent the entry of flood waters. They may also need to be reinforced. Care should be taken, however, that the walls are strong enough to support the pressures added by vent and window reinforcements. Also, the wall itself should be treated or constructed to prevent large amounts of water from passing through it.

Openings which are no longer necessary, such as old coal chutes, windows into storage and basement areas or unused doorways, can be permanently closed and sealed by masonry or reinforced glass block construction. Masonry enclosures should be "keyed" into the existing masonry in a manner similar to the original construction (Figure 27).

Where openings in exterior walls are necessary to the everyday function of the buildings, there are several flood proofing alternatives. Figure 28 illustrates four alternatives. Figure 28 illustrates four alternatives ranging from partial closure to complete closure. A variety of materials and combinations can be used in window closure. Possibilities include the partial bricking in of wall openings with or without metal shields; the use of wood timbers which fit in slotted jamb supports, and the provision of full metal shields. There are many others.



New brick used in closure

Windows can be equipped with flood shields and still be attractive. Figure 29 is an example in which an aluminum skin covers the brackets to which the bulkheads are bolted.

Figure 30 shows a shield over an air vent which is located in a pedestrian mall to prevent entry of flood waters into the subsurface part of a building. The shield is stored in a nearby garage and is carried by several men when it must be put into position.

Smaller wall openings such as service chutes, vents, or windows can be sealed as in Figure 31. This type of closure requires little alteration to the building and can be installed in a minimum of time

Display Windows

There are several approaches to adjusting display windows to prevent the entry of flood waters. Since these windows are so vital to store operation, they must remain attractive and function as a place of display for as long as possible. One approach is to equip the

Figure 27.-Masonry closure for unnecessary windows. The closure is keyed into the existing masonry to provide strength.

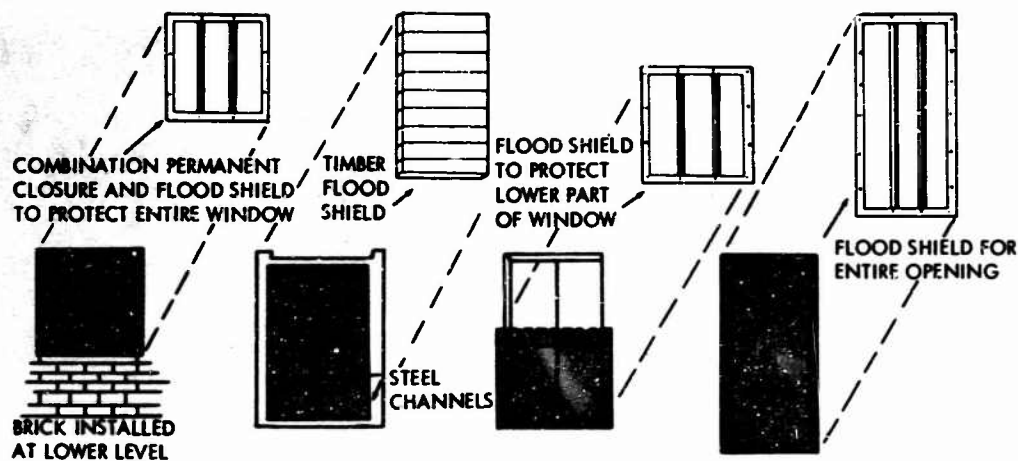


Figure 28.-Types of exterior wall flood proofing closures. These sketches illustrate several approaches which can be employed to flood proof openings in outer walls.

display window with an aluminum flood shield which can be bolted into place on the inside during floods but which can be stored at the back of the display area at other times. A typical installation is shown in cross section in Figure 32. When a flood is expected, the contents of the window are removed and the shield moved forward on a track and bolted into place approximately four inches behind the glass. Rubberized gaskets provide the waterproof seal around the edges of the shield. A show window with a flood shield in place is shown in Figure 33. A portion of the glass has been cut away to show the location behind the plate glass window.

"Weep holes" are openings provided at the base of a window frame to be opened when the shield is bolted into place. This permits flood waters to enter behind the glass to counter the outside pressure and prevent breakage. At such installations it is also necessary to protect the glass window from floating debris or ice. Rigid awnings, timbers or metal screens can be placed in front of the window for this purpose.

Another type of flood shield arrangement is one that is counter-balanced on the inside and above the window. This method allows an "open" view of the store interior, as shown in Figure 34.

The flood shields shown in Figures 32, 33, and 34 are designed to close off the entire window area, but this may not always be necessary. Flood shields can be designed to protect against a much lower flood, closing off only the lower part of a window.

Display windows can also be flood proofed by placing flood shields on the outside. Such shields will have to be stored elsewhere and carried into position when needed. An advantage of outside shields is that there is no need to protect the glass against the impact of debris or ice. It would be desirable, however, to provide openings to permit drainage of any seepage that might collect between the temporary closure and the glass. This drainage would be channeled into the building and pumped out above the flood levels.

There are advantages to both inside and outside flood shields. If the shields are on the outside of the window, the water pressure against them helps to seal the shield against the framework. If the shield is on the inside, it is within reach. Checks for leakage can be maintained and any problem with a shield can be corrected more easily if the bolts are inside and accessible rather than outside and perhaps submerged.

Pedestrian shopping arcades or first floor-level setbacks lend themselves to flood proofing measures as indicated in Figure 35. Here the flood shields are hinged from

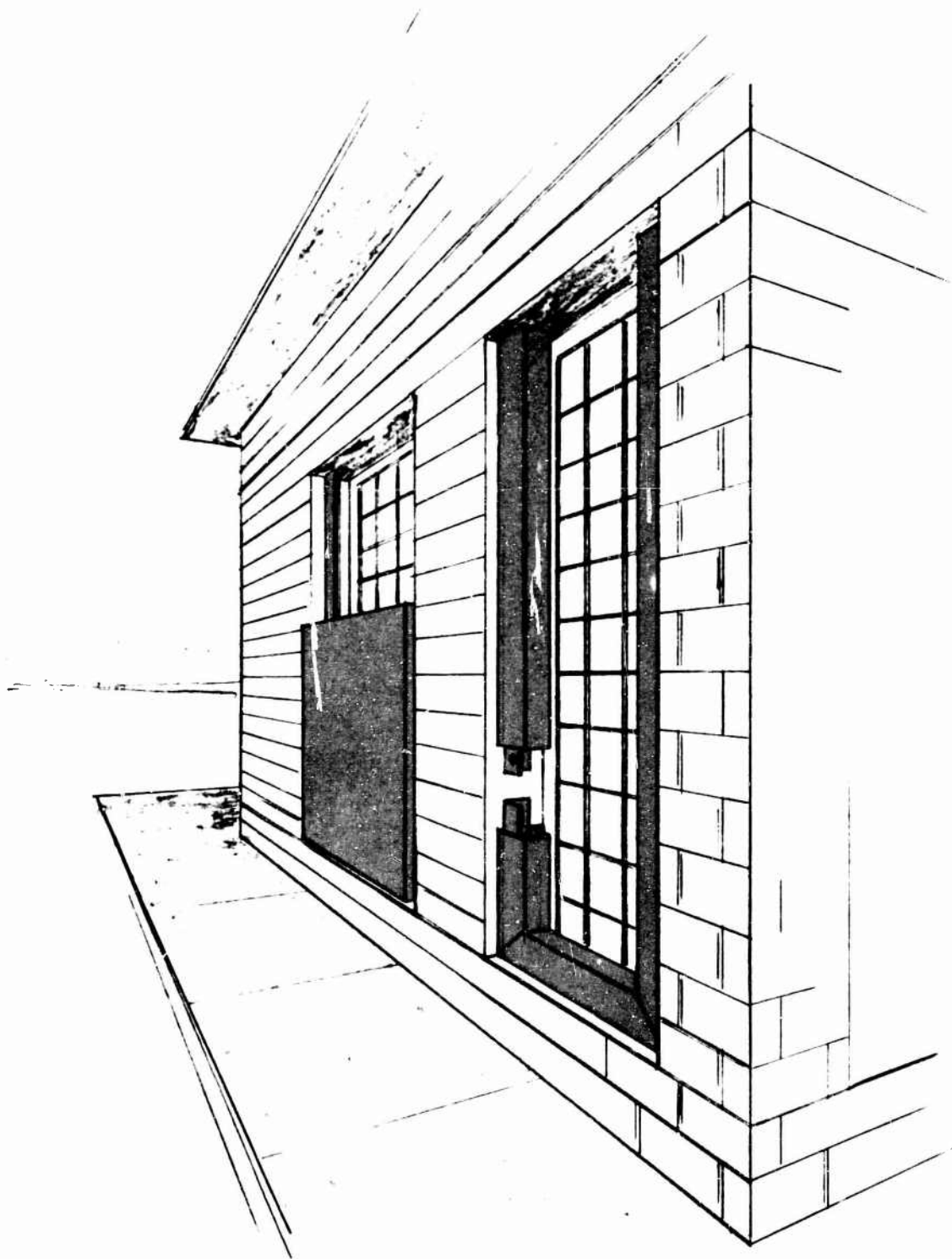


Figure 29.-Flood shields for windows. The window on the left has a flood shield in place. The window on the right shows the aluminum skin which hides the brackets for the shield.

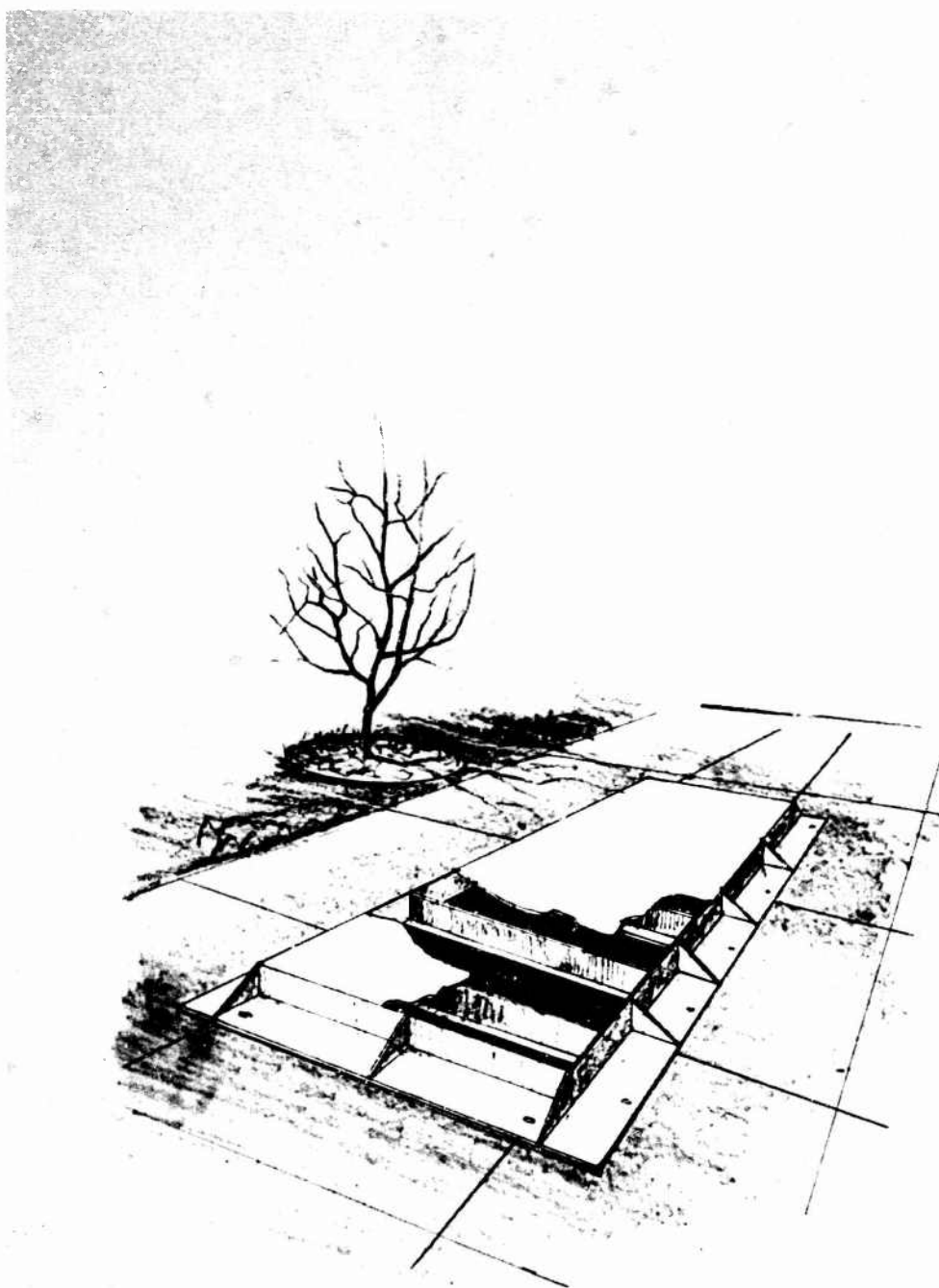


Figure 30.-Flood shield in place over an air vent. This shield prevents flood waters from entering the subsurface of a building through the air ducts.

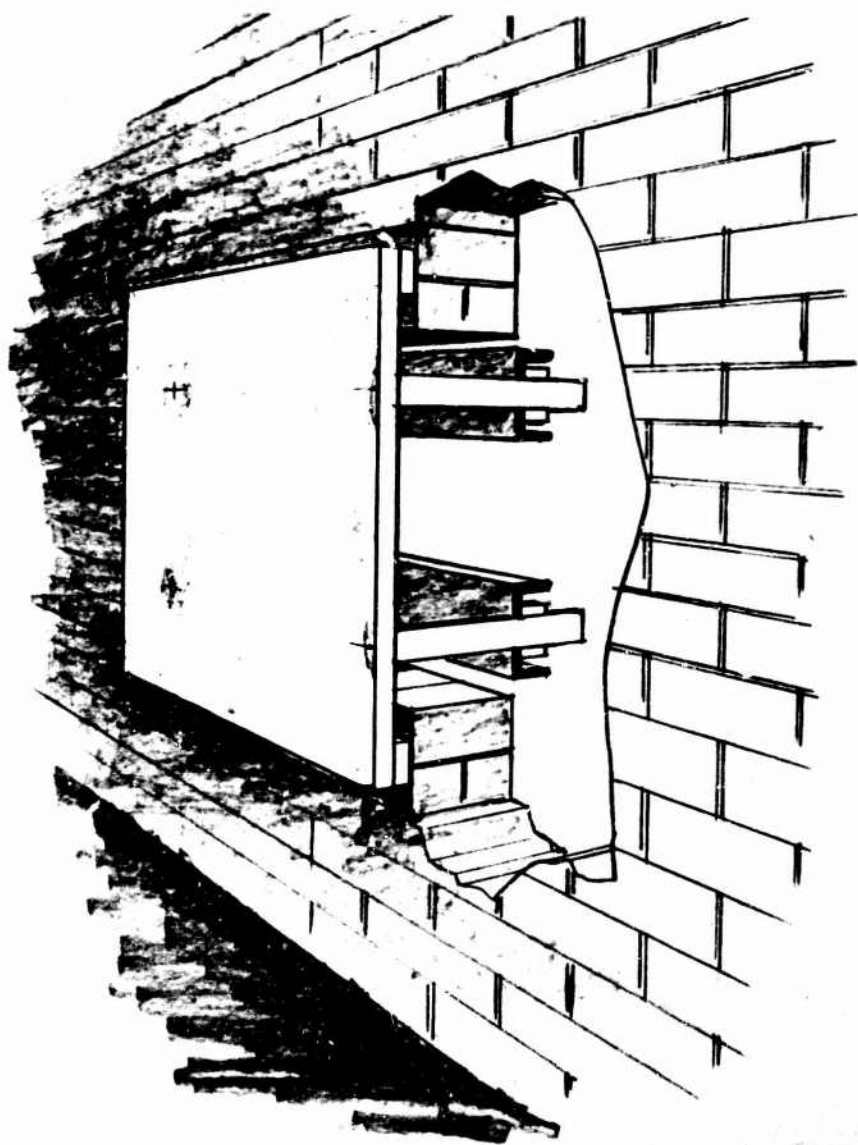


Figure 31.-Closure for small openings. This type of flood shield is easily installed and has little adverse effect on a building's appearance.

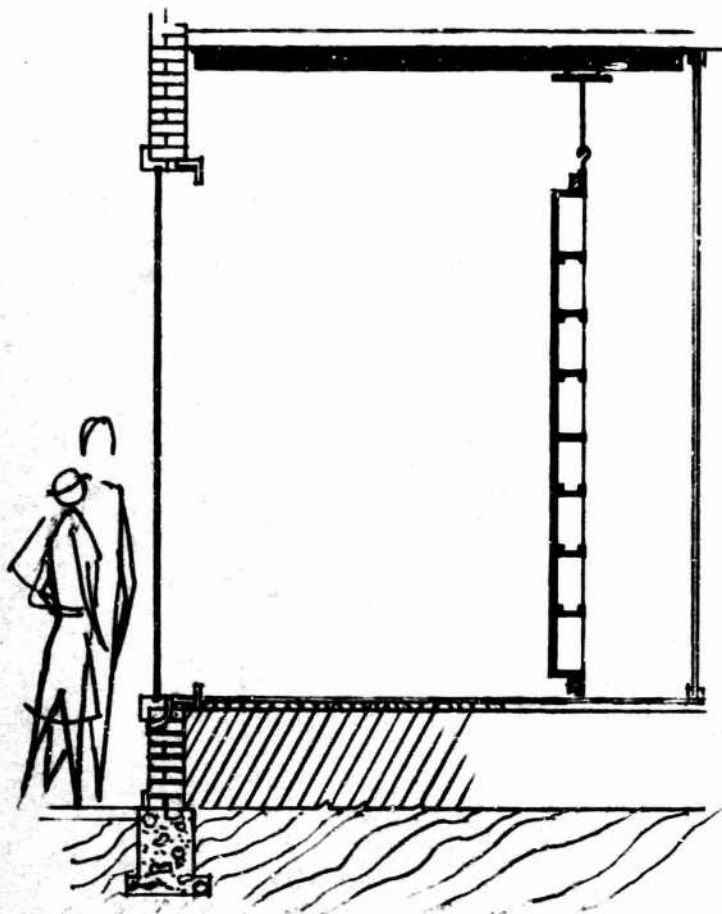


Figure 32.-Cross section of show window illustrating aluminum flood shield. When floods are anticipated, the shield which is suspended from a rack is moved forward and bolted onto the frame on the inside of the glass.

the ceiling on the outside of the windows. They are tied back against the ceiling in their stored position.

Another method of flood proofing large window areas which are not used for display purposes is employed in the Pittsburgh Press Building. In this case (see Figure 16), the large windows were replaced by small panes of $5/8$ inch structural glass inserted in a steel grid designed to resist the hydraulic loads imposed by the flood waters. This window construction resists the entry of flood water while still providing a source of natural light.

Doorways

Whether a doorway is for public, personnel or freight use will influence the measures employed to effect closure during a flood.

At a public entrance the framework installation for a flood shield should either be covered during flood-free periods or designed so that it will not detract from the physical appearance of the doorway (see Figures 14 and 15). As shown in Figure 14, flood shields can be counterbalanced above doorways and recessed into the ceiling during storage. When a flood warning comes, the shields are pulled down and bolted into place.

Another measure is to raise doorway thresholds, with access provided by gently sloping pedestrian ramps. The height of the sill will determine the level of permanent

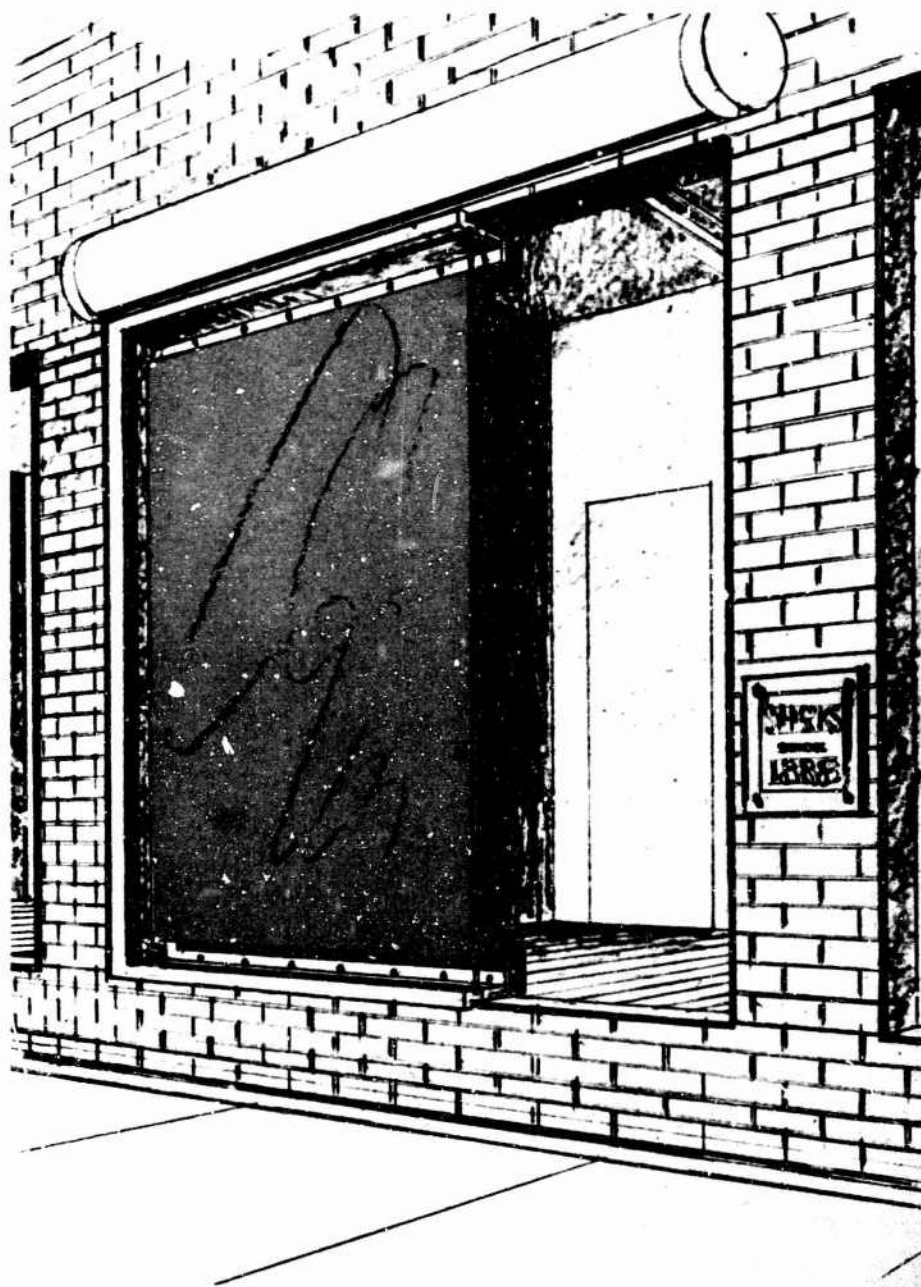


Figure 33.-Aluminum flood shield in position at a show window. The glass is cut away to show its location 4 inches behind plate glass.



Figure 34.-Counter balanced flood shield in stored position above show window. This type of shield preserves an open view of the store.

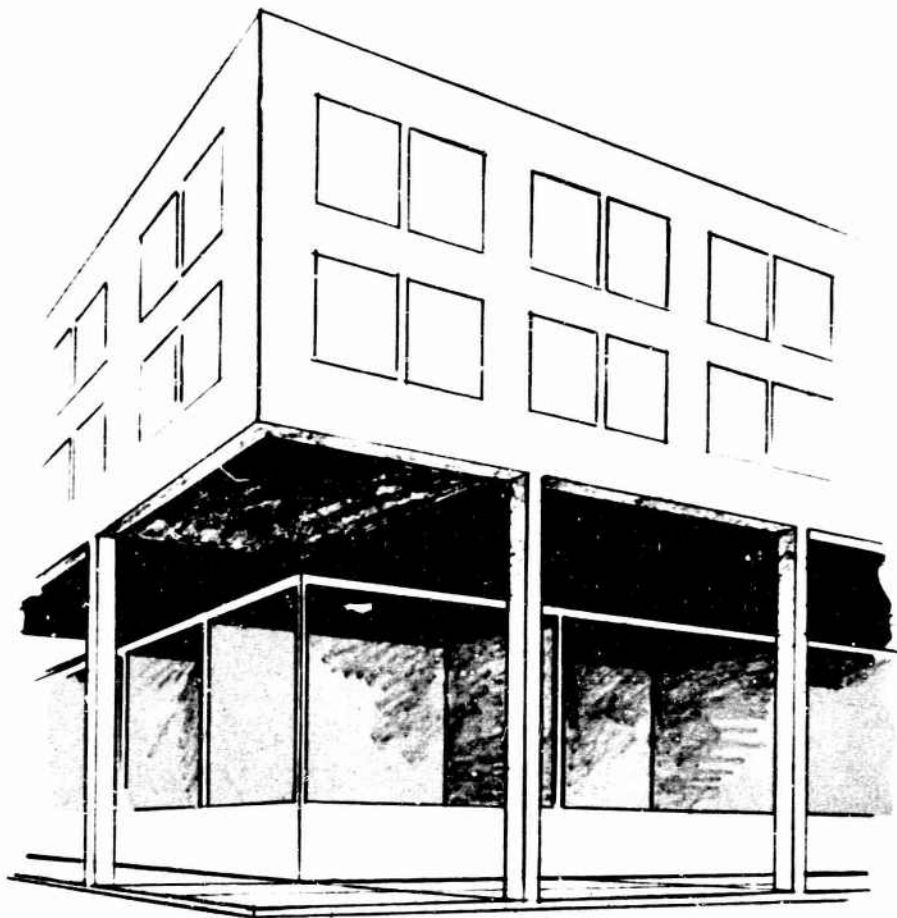


Figure 35.-Flood shields at a shopping arcade. These shields are hinged on the outside of the display window on the ceiling above the arcade and drop down in front of the glass.

flood proofing. In some cases, this level can be raised by using contingent and emergency flood proofing measures.

At entrances for building personnel, or other service entrances, flood shields can be entirely functional. Figure 36 illustrates an entrance where the flood shield slides along on a rack on the outside wall beside the entrance it is designed to close. When flooding threatens, the shield can be slid into position and bolted into place. In many cases small steel security doors can also become flood shields when gaskets and bolts are provided to make them watertight.

Figure 37 is a photograph of a large flood shield in storage position. When floods threaten, the grill on the floor at the entranceway is taken up and the massive door is moved along the track into position over the doorway and bolted into place. The sketch in Figure 38 illustrates a flood shield ready to be bolted into place. A neoprene gasket around the edge makes a watertight seal against the frame.

Figure 39 shows flood shields which protect the loading dock area at a department store. These shields are hinged on top and can be lowered (flap down) into position against the loading dock after the wooden bumpers have been removed and then bolted into place. Ropes used to lower the shields are attached to the large rings above them. At some doorways it is possible to design lightweight aluminum flood shields which hinge on the sides and close like any other door (Figure 40). The shields in this illustration also serve as a fireproof door.

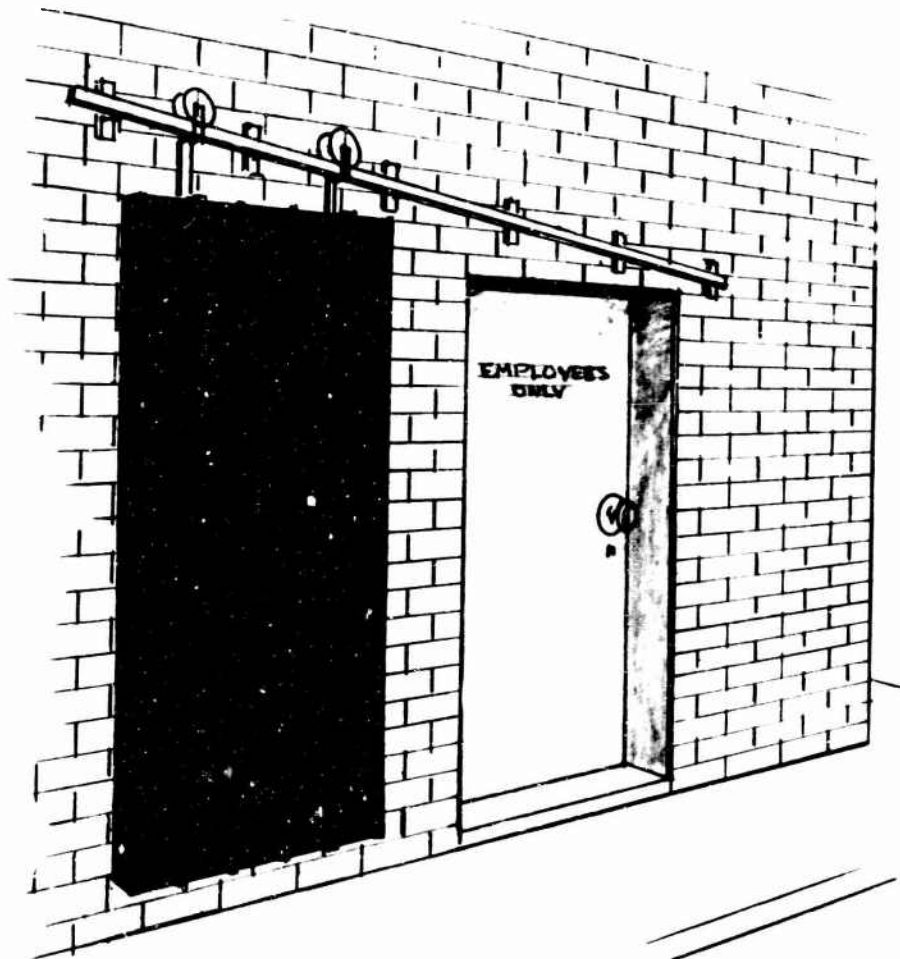


Figure 36.-Sliding flood shield in open position. This shield is for a service entrance and is strictly functional.

Flood shields can be secured in a number of ways. Some shields are bolted onto their frames only on the tops and bottoms (Figure 41), while others are bolted against the receiving frame on the sides (Figure 42). Whatever the method used, care must be taken to assure that the gates have a watertight seal against the frame. This can be achieved by applying uniform pressure on the gasket or seal through a proper design of bolting patterns and by using caulking compounds, binding agents, oakum, or lead wool, to control leakage.

Flood shields for doorways need not cover the entire doorway, they may only extend to the elevation of the selected flood protection level. Because of structural limitations, the building shown in Figure 43 is equipped with flood shields to protect against only a three-foot flood stage. If that stage is exceeded, this flood proofing measure will be overtopped thereby avoiding the build-up of pressures which could cause structural damage.

Flood proofing must be complete up to the selected level of protection. If an entranceway cannot be protected by a watertight flood shield because of its design, it will need to be closed off by emergency measures such as sandbags over vinyl sheeting backed with timbers.

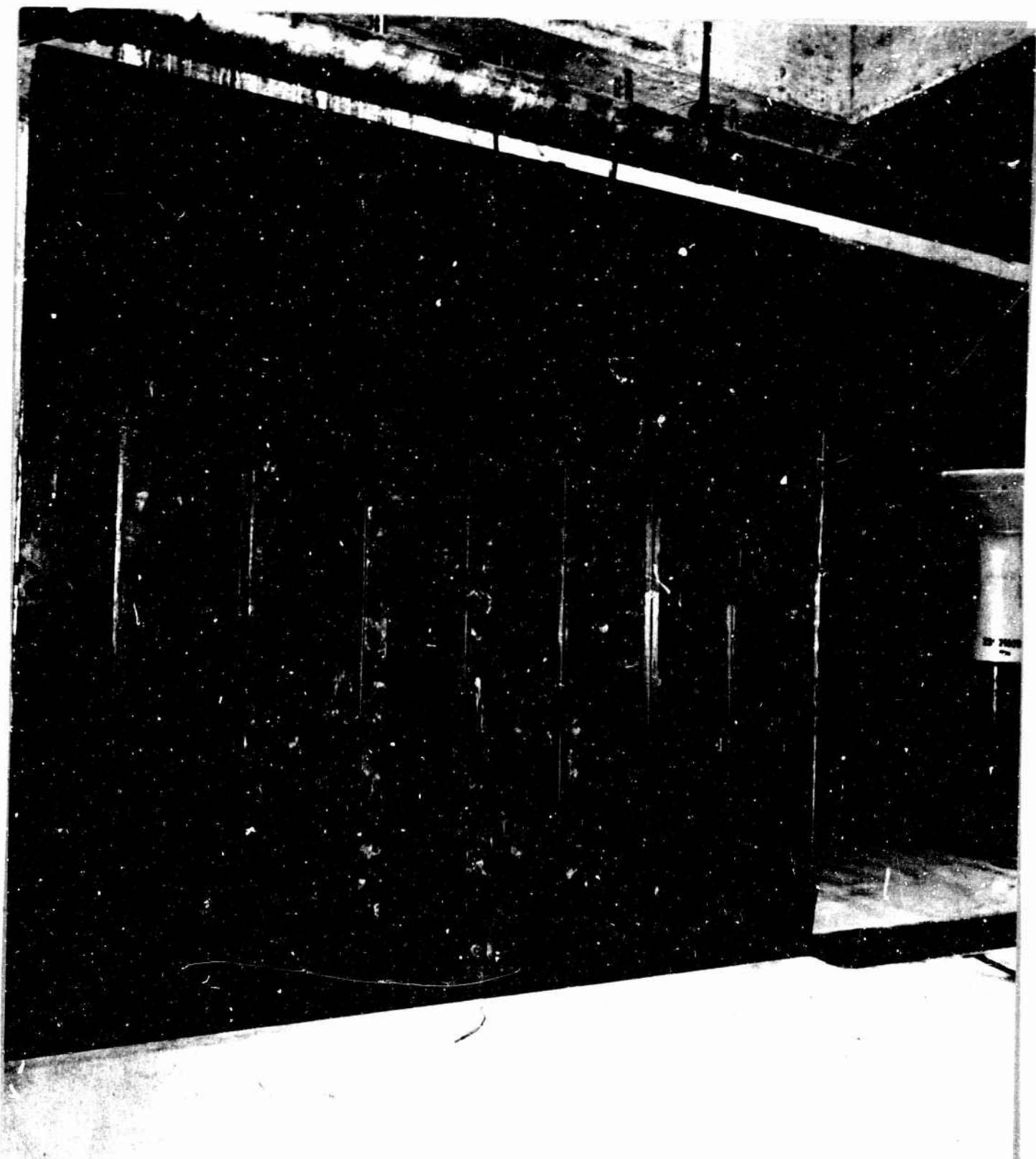


Figure 37.-Large flood shield in storage position. This shield was made to close off the automobile entrance to a large parking garage.

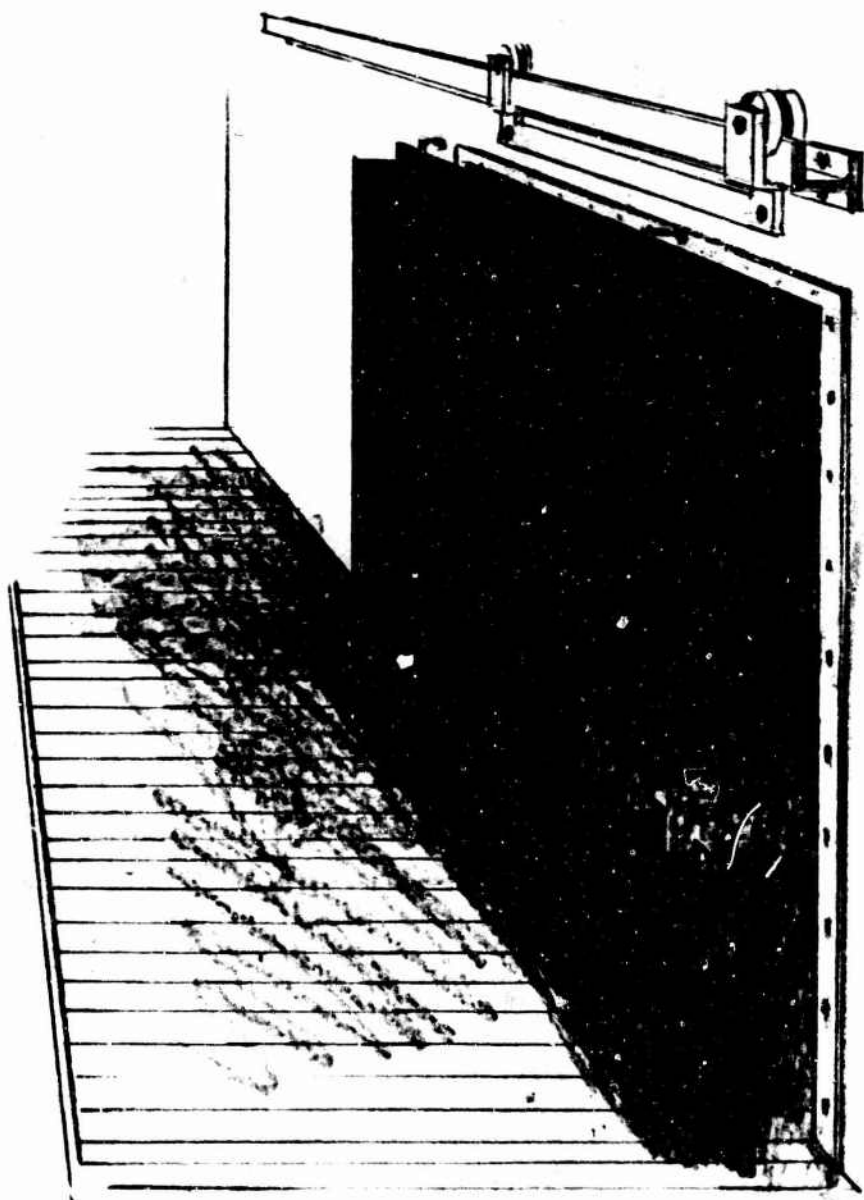


Figure 38. Large flood shield in position about to be bolted into place.

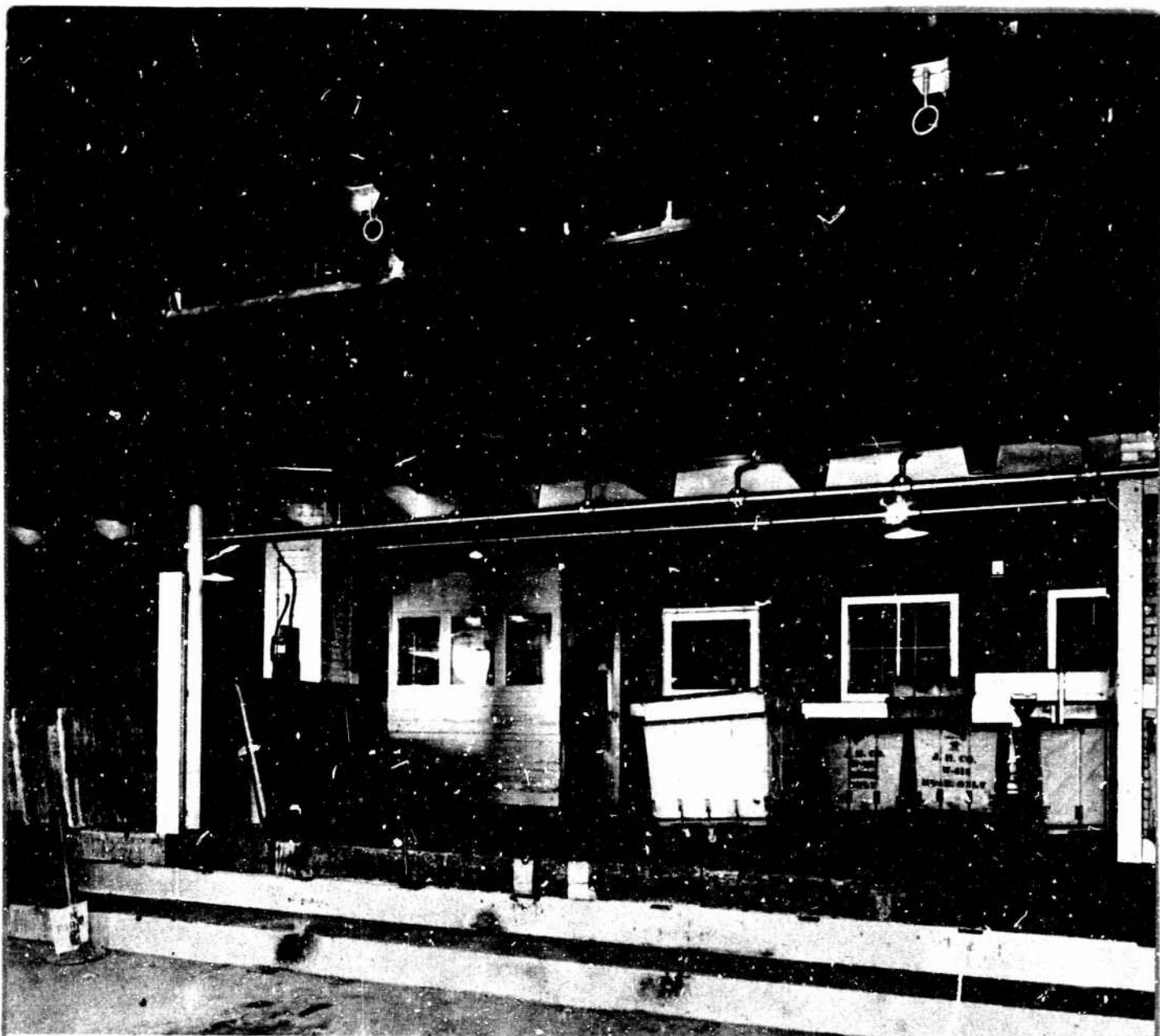
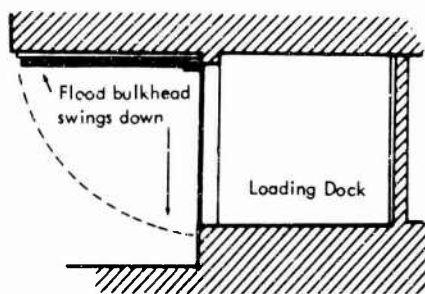


Figure 39.-Flood shields at a loading dock. These shields hinge from the top and drop down to prevent the entry of water. The insert illustrates how the shields can be put in place.



(Photo by Horne Department Store, Pittsburgh, Pennsylvania.)

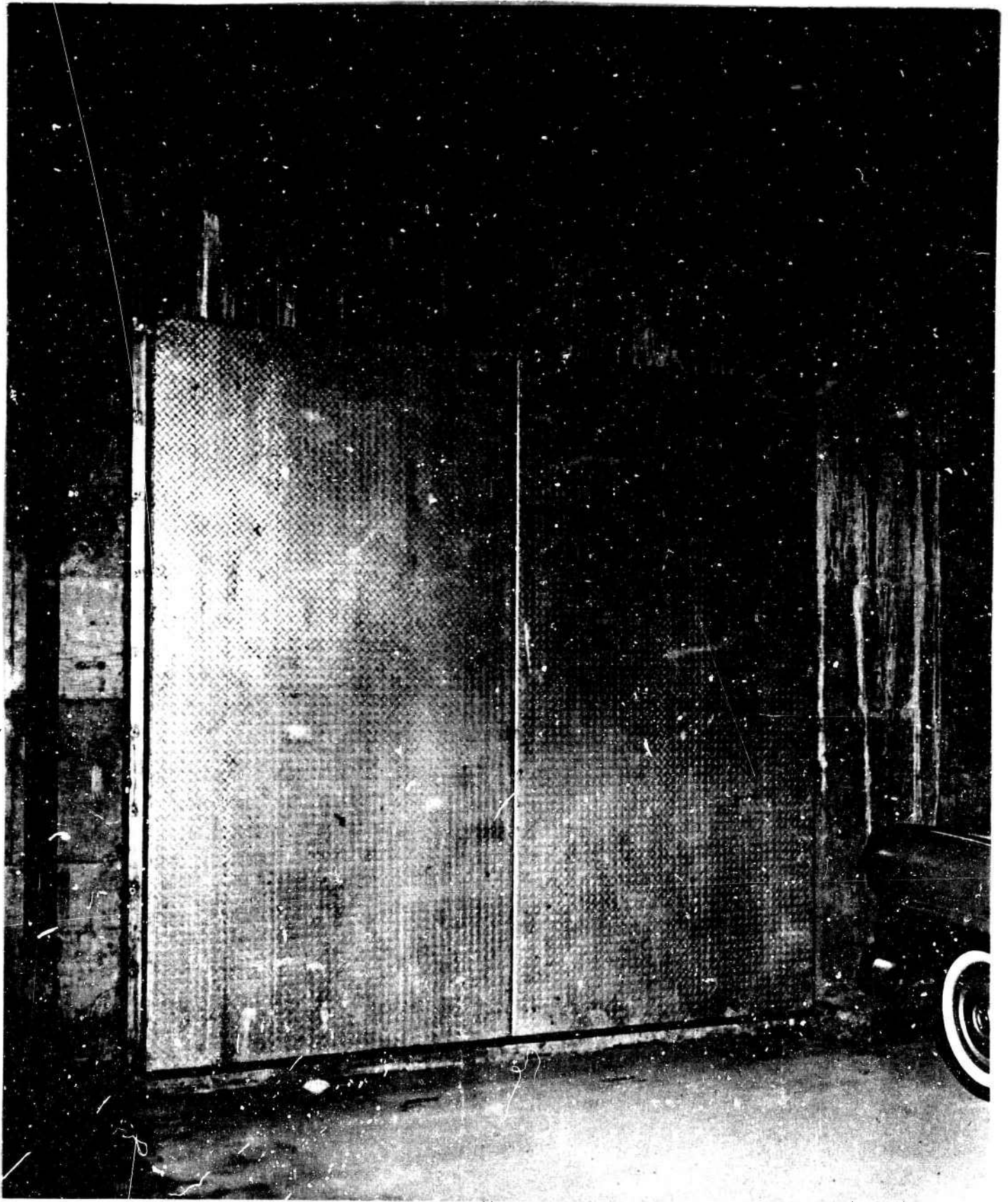


Figure 40.-Hinged flood shields which also serve as a fireproof door.



Figure 41.-Flood shield at warehouse which is secured on the top and bottom.

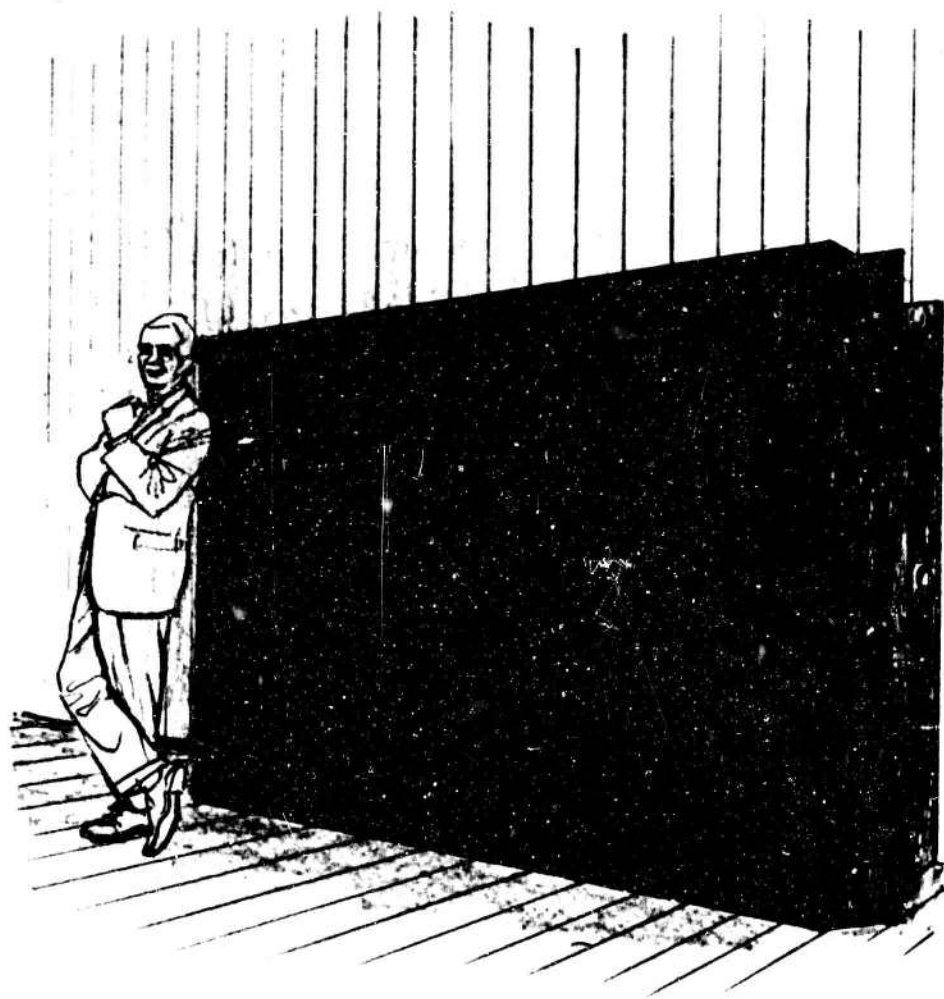


Figure 42.-Flood shield at warehouse which is secured on sides.

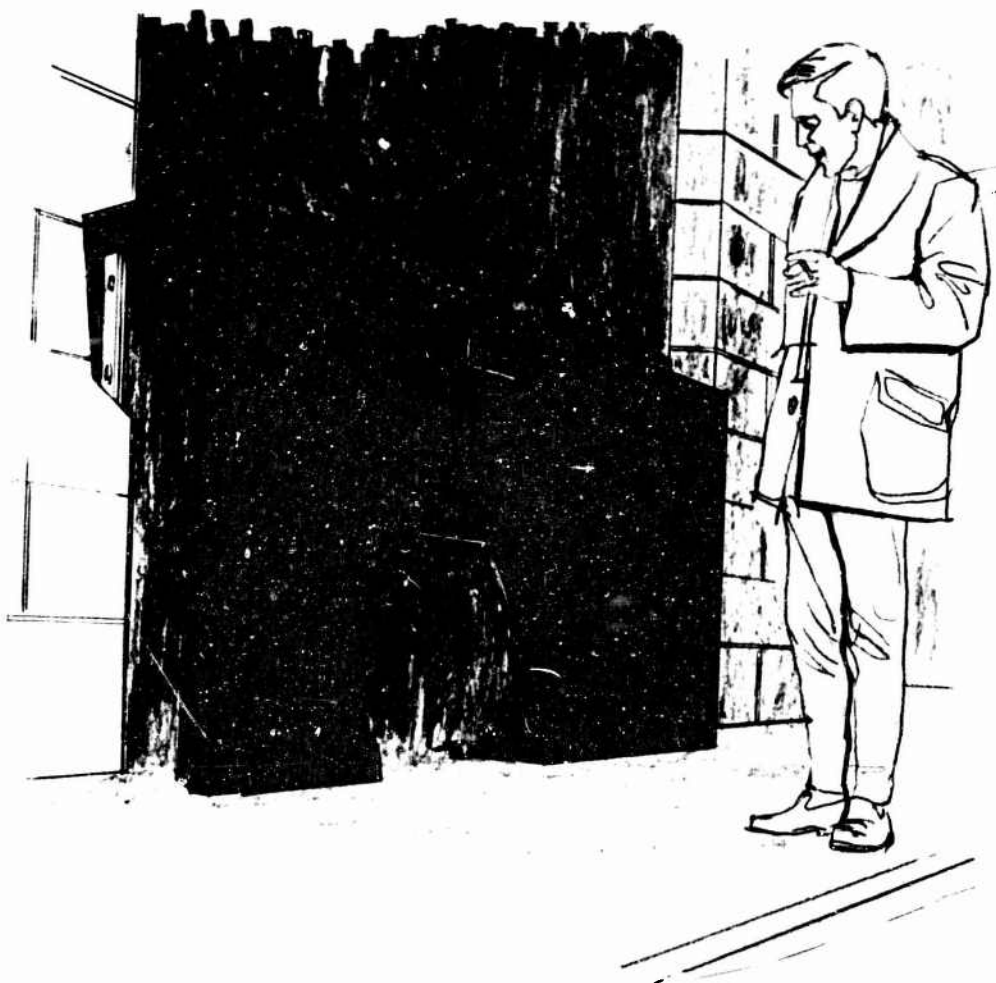


Figure 43.-Flood shield protecting against a 3 feet flood stage.

Evacuation of Contents

When it is not possible to prevent the entry of water, temporary evacuation of building contents such as retail merchandise, records, files, office equipment, machinery, supplies and other valuables can significantly reduce flood damage providing sufficient warning time is available. Materials located on lower levels of a building in a flood area can be mounted on rollers or moveable pallets for easy transfer to a flood-free elevation. Figure 44 shows moveable counters used in the basement of the Horne Company department store in Pittsburgh. When floods threaten, they become vehicles for transporting the merchandise they contain as well as other items which can be stacked on top.

The Horne Company's flood manual contains a schedule for the removal of merchandise from the basement and first floors to higher floors as specified flood heights are reached. The floor areas are zoned and merchandise from a particular zone is moved to an assigned area on a higher floor. Each zone has specific elevators assigned to it and store employees are organized in teams to handle the movement.

An orderly plan of merchandise removal means faster, speedier recovery from flood effects by store, office, or factory. Less "shut-down time" means smaller flood losses since a drop in sales or production attributable to flooding is as much a part of the flood loss as the direct damage to property.

Flood Proofing Houses

Houses should not be located on flood plains when suitable sites are available on flood-free land. In some places, however, there may be no choice, especially where virtually an entire urban area, including the residential sections, is subject to inundation. Residential construction does not lend itself readily to flood proofing because of the extensive use of materials that do not impede the passage of water. Moreover, houses are seldom designed to withstand any significant horizontal pressures.

Where circumstances require the location of a residence on a flood plain, certain flood proofing measures can be incorporated into the design of the house as discussed in Chapter III.

In most cases in which an owner has purchased a finished house in an area subject to flooding, his success with flood proofing will depend on whether flood stages are low on his property and whether the outer walls of the structure are reasonably impervious. Under these conditions, flood shields can be designed to restrict the entry of water through openings in the walls, providing the walls are strong enough to resist flood induced pressures. This approach is illustrated in sketch form in Figure 45 and photographs of an application of it are shown in Figure 46. To be effective, the flood proofing program must also include measures to cope with sewer backup and ground-water seepage.

Homeowners who have suffered severe basement flooding should consider the relocation of furnaces, hot water heaters, washers, dryers, air conditioners, freezers, refrigerators, power shop equipment and other appliances as a permanent flood proofing measure. The length of the list dramatizes the large investment many people have in items which often are located in basements subject to flood damage.

A Flood Proofing Plan for a Structure

The flood proofing of a structure is analogous in many respects to making a ship watertight and seaworthy. Flood proofing involves not only adjustments to the foundation and substructure, but also modifications of those parts of the superstructure that are below anticipated flood levels.

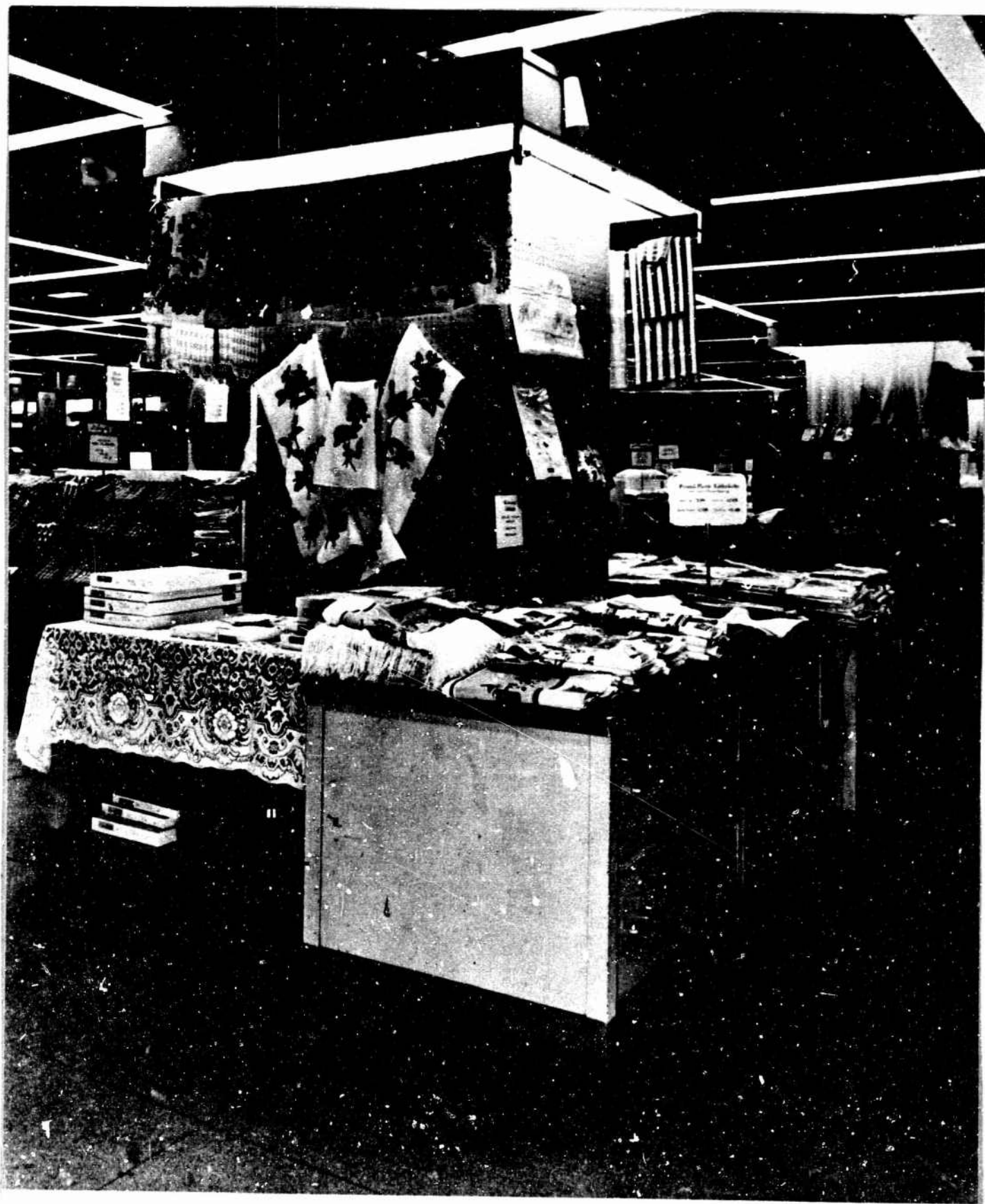


Figure 44.-Display counters mounted on rollers. When flooding threatens, these counters are used as carts to carry merchandise to designated points on higher floors. (Photo by Horne Department Store, Pittsburgh, Pa.)

A Flood Proofing Checklist

Some major items that should be considered in any plan for flood proofing a building are:

For Foundations and Substructure

1. Closure of openings including doors, windows, and vents.
2. Waterproofing and/or reinforcement of basement and foundation walls.
3. Reinforcement or drainage of floor slab.
4. Valving off or termination of entering utilities.
5. Continuation of internal building utility systems.
6. Protection for immovable equipment.
7. Plans for the removal of stock.
8. Procedure for implementing flood proofing.

For the Superstructure

1. Closure of windows, door and vents.
2. Anchorage and reinforcement of floors and walls.
3. Use of water resistant interior materials.
4. Evacuation of contents.
5. Reorganization of space.
6. Emergency protection measures.
7. Procedure for implementing flood proofing.

As noted on the checklist, measures requiring the presence of trained or experienced personnel are important features of a flood proofing program.

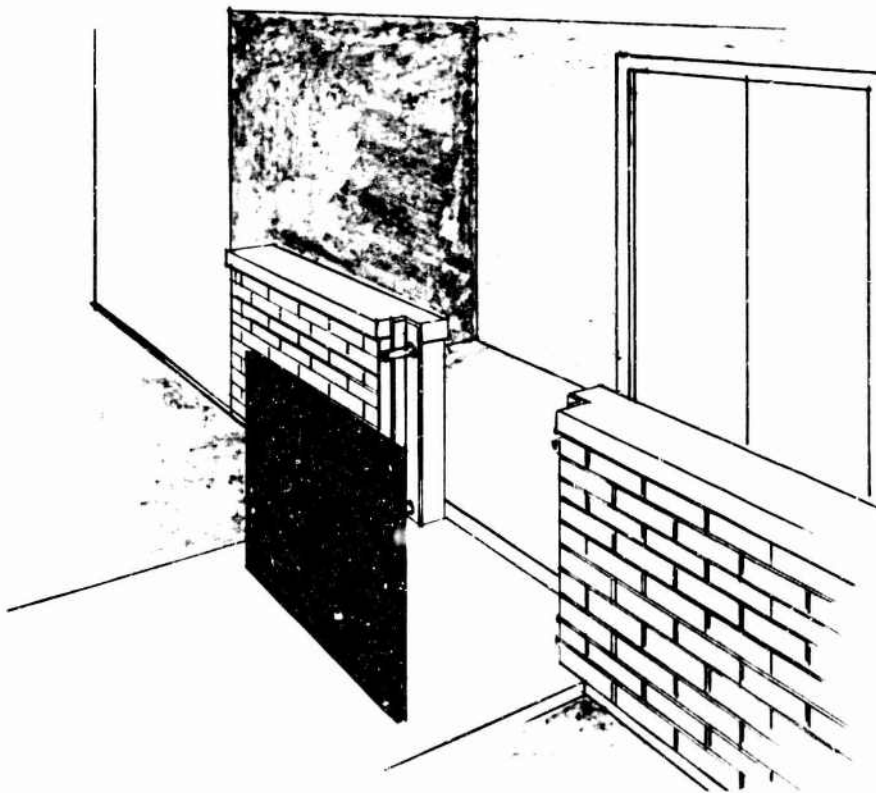
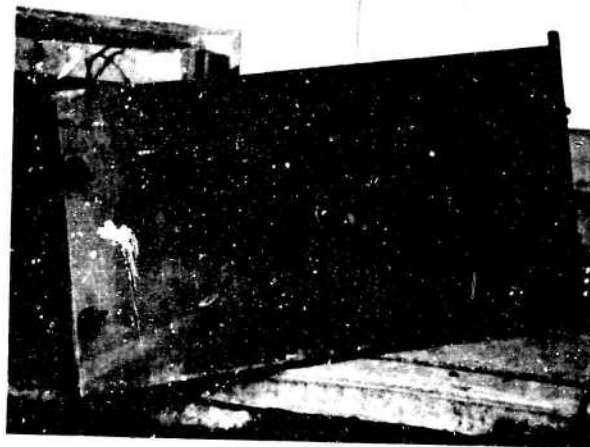


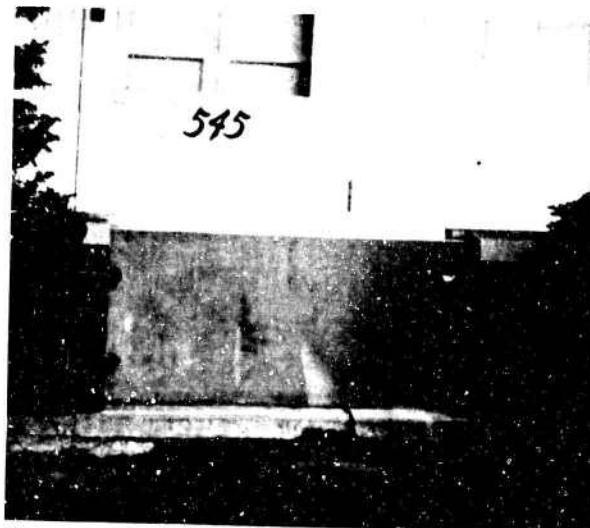
Figure 45.-Flood shield to protect a home. This type of shield can afford protection against a 3 feet flood stage.



Front entrance of house that has been flood proofed. Brick wali was added to close off much of the front porch. The brackets or flanges on the edge of the brick are used to secure the aluminum flood shield which closes off the opening during floods.



Aluminum flood shield. A 1" thick slab of aluminum that is about to be bolted on to the flanges in anticipation of a flood.



Flood shield in place. This shield is designed to withstand a flood stage of 2.5 feet.

Figure 46.-Flood proofing at the Stanley House, LaGrange, Illinois. (Photos by E. Lee Stanley.)

Flood Proofing Benefits and Costs

To be economically sound, the incremental benefits which would accrue from flood proofing a structure should equal or exceed the cost of flood proofing. A survey analysis of Bristol, Tennessee-Virginia, showed that flood proofing could be economically feasible and could be considered as an alternative to flood control programs.

Community Benefit-Cost Findings.-Certain substantial structures in Bristol which represented large investments and would suffer heavy losses if flooded, were found to be the structures that could be most readily flood proofed. It was shown that selective flood proofing of these structures would result in extremely high benefit-cost ratios. Sixteen structures in Bristol were found to account for over 62 per cent of the total potential damage from a recurrence of the 1929 flood of record and 36 per cent of the total potential damage from the regional flood.

Subsequent studies of the feasibility of flood proofing selected structures in four other communities have been carried out by the cities with technical assistance by the Tennessee Valley Authority.¹ In these studies, flood proofing was considered as a part of a comprehensive plan for flood damage prevention. It was employed in these plans primarily to reduce the residual damage that remains after partial protection by a flood control project.

In Athens, Tennessee, an analysis of the feasibility of flood proofing several of the substantially constructed buildings showed that in the course of time, the benefits in flood damage avoided would outweigh the initial cost of flood proofing by approximately 5 to 1. Similar ratios of benefits to costs for flood proofing selected buildings were found in other studies.

Benefit-Cost Factors.-Though the economic feasibility of flood proofing has been demonstrated for substantial buildings in several small cities, the comparative costs of flood proofing particular buildings will vary considerably depending upon:

1. Local flood characteristics,
2. The type and size of the structure to be flood proofed,
3. The extent of efforts to make the measures esthetically pleasing, and
4. The financial terms of capital invested in flood proofing.

Correspondingly, the potential benefits that would accrue would vary with:

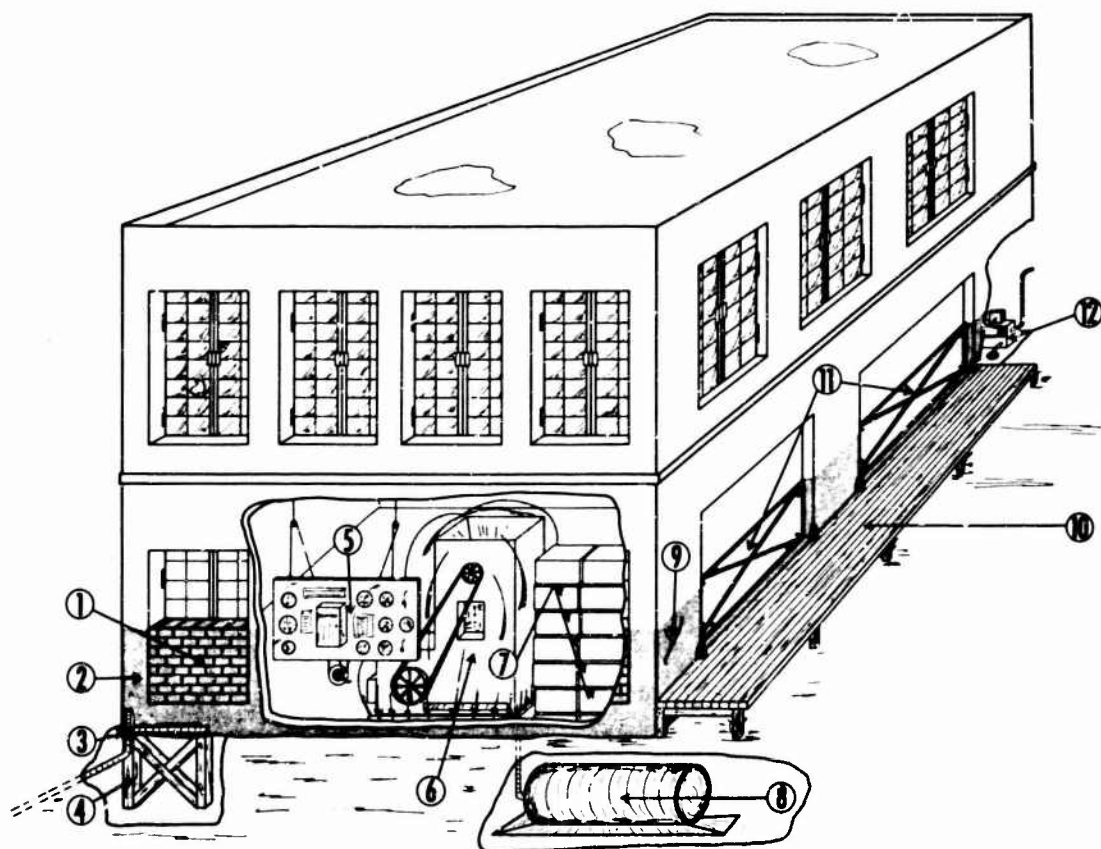
1. The amount of investment in the structure,
2. The intensity of use, and
3. The elevation to which the flood proofing measures are carried.

The economic feasibility of a flood proofing plan for a specific building should be based on an evaluation of the above factors for the particular building. Once the potential flow of benefits has been established on an average annual basis and the average annual cost estimated, the feasibility of flood proofing can be expressed in benefit-cost terms.

Tax Considerations.-Another point that deserves attention is the tax aspect of flood proofing. At present, the attitude of the Internal Revenue Service toward flood proofing measures appears to be generally favorable. The amount of depreciation allowed and the rate of depreciation would be influenced by the nature of the material used.

The main point is that the expenses of flood proofing could to some extent be used to reduce one's tax liability. This fact might lower the real cost of flood proofing and might influence the decision on whether or not to flood proof. Local Internal Revenue Offices should be consulted to determine the specific tax effect of flood proofing a given building.

¹In addition to Bristol, the communities studied were: Athens, Redbank-White Oak, and Sevierville, all in Tennessee, and Coeburn in Virginia.



EXPLANATION

1. Permanent closure of opening with masonry
2. Thoroseal coating to reduce seepage
3. Valve on sewer line
4. Underpinning
5. Instrument panel raised above expected flood level
6. Machinery protected with polyethylene covering
7. Strips of polyethylene between layers of cartons
8. Underground storage tank properly anchored
9. Cracks sealed with hydraulic cement
10. Rescheduling has emptied the loading dock
11. Steel bulkheads for doorways
12. Sump pump and drain to eject seepage

Figure 47.-A flood proofed structure. This sketch illustrates the many items that must be employed to flood proof a structure.

A Flood Proofed Structure

For full effectiveness both the technical and financial aspects of flood proofing should be coordinated in a total plan for each building. Figure 47 illustrates some of the physical features of such a plan. In that example, the structure has been adjusted to withstand flooding from ground water seepage, sewer backup, and overland flow, up to a predetermined protection level. Each flood proofed building should have such a plan to show the relationship among the various protection measures. In addition, costs should be associated with each of the measures depicted and alternative financial solutions defined to determine both feasibility and the optimal amortization schedule. An evaluation of such plans would assist in determining the adequacy of a flood proofing program.

Flood proofing of selected buildings can be an effective means of reducing potential flood losses. It merits consideration when plans are being formulated for flood plain management. Its availability broadens the range of choice that property owners can consider when faced with the need for taking action to reduce flood risk.

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